BACTERIOLOGICAL SOURCE STUDY
ST. CATHARINES BEACHES
1984 - 1985

October, 1986

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Ontario
Ministry
of the
Environment

B.I. BOYKO, Director
West Central Region

MINISTRY OF THE ENVIRONMENT
APR 0 1 1987
HAZARDOUS CONTAMINANTS
BRANCH

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ST. CATHARINES BEACHES

1984 - 1985

TECHNICAL SUPPORT SECTION

Ontario Ministry of the Environment
West Central Region
October, 1986

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EXECUTIVE SUMMARY

Four St. Catharines beaches on Lake Ontario have been continuously posted since 1983 due to elevated fecal coliform levels. In addition, these beaches were posted periodically in many previous years.

During 1984 and 1985, field investigations and instream surveys were conducted to identify and quantify bacterial contamination sources that resulted in these beach postings. Twelve Mile Creek was determined to be the main contamination source during the 1984 surveys with the Old Welland Canal as the principal contributor. However, during the 1985 surveys, upstream sources also contributed significantly to water quality degradation.

Three main sources of bacterial pollution were found during the 1984 surveys. These were the Centennial Park combined sewer and the effluents from the Ontario Paper Company and Domtar Construction. In addition, ten dry weather combined sewer overflows were found discharging to the Twelve Mile Creek system in the City of St. Catharines. All sources were reported to the City. After the 1984 survey and prior to the 1985 survey, the Centennial Park sewer and the overflows were corrected and consequently minimal bacterial loads were contributed by these sources.

During the 1985 surveys, three main sources of bacterial pollution were identified. These were Carter Creek and the effluents from the Ontario Paper Company and Domtar Construction. The Carter Creek discharge had increased to levels similar to those which were discharged from the Ontario Paper Company and Domtar Construction. In addition, background levels monitored in Twelve Mile Creek at Glendale Avenue were 10 to 30 times greater than the 1984 levels. Three dry weather overflows were discovered discharging to the buried portion of the Old Welland Canal. These sources were reported to the City of Thorold. To date, the City of Thorold is still investigating means of correcting these overflows.

ACKNOWLEDGEMENTS

We wish to express our appreciation to Michael Young and Susan Janhurst of the Microbiology Laboratory, Ontario Ministry of the Environment, Rexdale, for co-ordinating the bacterial analysis of water samples taken for these surveys. Water samples for both surveys were collected and data compiled by summer student workers hired by the Ministry of the Environment. Additional personnel were employed in Hamilton and Welland on Canada Works Projects under the Unemployment Insurance Commission Section 38 Job Creation Program.

We would also like to acknowledge the Niagara Regional Health Unit and the Cities of St. Catharines and Thorold Engineering Departments for their assistance in setting up surveys and their promptness in taking corrective measures in abating sources as discovered.

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1.0 INTRODUCTION

1.1 Beach Closures

Along the southwestern Lake Ontario shoreline at St. Catharines, there are five sandy beaches. For the past three years, four of these beaches, namely Lakeside Park, Michigan, Municipal and Garden City (Figure 1.1), have been continuously posted to public bathing by the Niagara Regional Medical Officer of Health. These postings are due to fecal coliform levels in the water exceeding Ministry of the Environment (MOE) swimming guidelines (1). The guidelines state that a potential health hazard exists if the geometric mean of fecal coliform density for a series of ten water samples exceeds 100 organisms per 100 milliliters of water (100 org/100 ml).

The health risk to swimmers is associated with pathogens which include bacteria, fungi, protozoa and viruses carried by the water or resuspended from the bottom sediments by the bathers and/or wave action. Contact with these pathogens may cause infections of the skin, gastro-intestinal tract or upper respiratory system. Densities of fecal coliform bacteria at any one beach may be influenced by many factors such as discharges from rivers, wastewater, storm sewers, drainage from agricultural land, birds, swimmers, sunlight, lake roughness, lake currents and water turbidity.

1.2 Previous Studies

Previous studies carried out by the MOE in 1983 indicated that the high waterfront bacterial levels were mainly attributed to the outflow from Twelve Mile Creek. Under normal lake conditions, the plume from the creek would frequently blanket the beaches. In addition, it was shown that the contamination in Twelve Mile Creek was a result of many point source discharges.

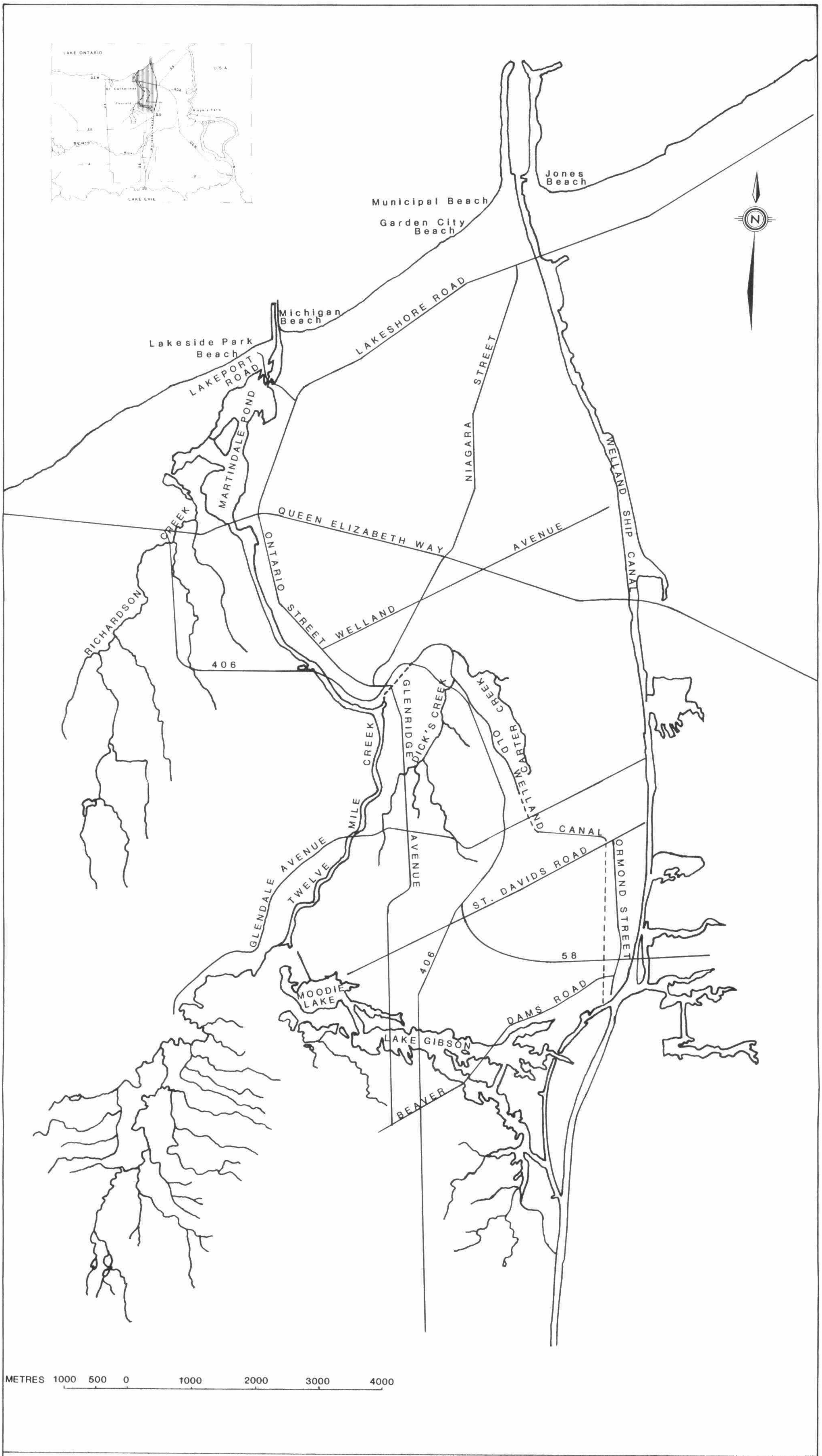


Figure 1.1 Location map of St. Catharines' Beaches Study Area

During the summer of 1978, a study was carried out by the Microbiology Section of the Laboratory Services Branch and the West Central Region of the MOE(2). This study attempted to evaluate the impact of the pulp and paper operations in St. Catharines and Thorold on the bacterial quality of the Old Welland Canal and Twelve Mile Creek. The study found that the paper mills have a substantial impact. However, other sources contributed to the bacterial pollution as well. The report recommended that further studies be carried out in order to identify the additional sources.

During the summer of 1983, the Great Lakes Section of the Water Resources Branch of the the Ministry of the Environment in conjunction with the Welland District office carried out a study on the St. Catharines lakefront to locate sources of bacterial pollution to the bathing beaches(3). Numerous small sources were found along the beaches especially during rainfall events, however, the Twelve Mile Creek outflow was identified as the major source with the Old Welland Canal being the major bacterial contributor. No attempt was made to locate individual sources of contamination to Twelve Mile Creek and the Old Welland Canal during this study.

As a result of these two studies and continuous beach closures, the West Central Region, Technical Support Section conducted both field investigations and bacteriological surveys in the St. Catharines/Thorold area during 1984 and 1985. These investigations and surveys were carried out to quantify and identify bacterial sources to the Old Welland Canal and Twelve Mile Creek. Bacteriological sampling was also carried out along the waterfront and the outlet of the Welland Ship Canal. The Niagara Regional Health Unit co-ordinated beach sampling with the MOE survey.

2.0 TWELVE MILE CREEK DRAINAGE BASIN AND STUDY AREA

2.1 Physical and Hydrological Features

The Twelve Mile Creek drainage basin, with a total land and water surface area of 150 km^2, is located in Southern Ontario along the southern shore of Lake Ontario (Figure 1.1). The drainage basin encompasses the majority of both the cities of St. Catharines and Thorold within its watershed boundaries. The remaining portions of St. Catharines and Thorold lie mostly within the drainage area of the Welland Ship Canal.

The main watercourses in the study area include the Welland Ship Canal, Twelve Mile Creek and the Old Welland Canal (Welland Canal #2). The majority of the water flowing in the study area originates from Lake Erie with diversions to the three main watercourses. The remaining water contributions include industrial, storm and combined sewer discharges, effluent from the Port Dalhousie and Port Weller sewage treatment plants and natural flow from headwater tributaries.

Twelve Mile Creek originates in the southern portion of the study area as a small natural stream with flow measurements of approximately 0.11 m^3/s (3.9 cfs) during the surveys. Water discharged from the DeCew Falls generating station increases this flow to approximately 180 to 200 m^3/s (6,400 to 7,100 cfs). This water is diverted from the Welland Ship Canal and routed via lakes Gibson and Moody to the generating station. Twelve Mile Creek receives little additional inflow during dry weather periods as it flows north to its confluence with the Old Welland Canal. (Figure 1.1)

The Old Welland Canal (Canal #2) begins in southern Thorold near the Ontario Paper Company Ltd. where 1.4 m^3/s (50 cfs) is diverted from the Welland Ship Canal. This diverted water is used to dilute the effluent discharged by downstream industries. It receives an additional 2.0 m^3/s (71 cfs) of industrial and municipal effluent as it flows north under Thorold and through St. Catharines to its confluence with Twelve Mile Creek. The largest single contributor is the Ontario Paper Company Ltd. which discharges 1.4 m^3/s (50 cfs) of treated effluent to the canal. The remaining major dry weather contributors are Fraser Inc. (0.33 m^3/s), Domtar Fine Papers Inc. (0.12 m^3/s), Hayes Dana Inc. (0.11 m^3/s), Domtar Construction (0.0099 m^3/s) and Kimberly Clark Inc. (0.080 m^3/s).

2.2 Land Uses and Population

The populations of the Cities of St. Catharines and Thorold are 124,018 and 15,412 respectively (4). St. Catharines constitutes approximately one-third of the total population of the Niagara Region, making it the largest urban area within the Region. The automotive industry is the largest industrial employer; other industries include pulp and paper, ship building, wineries, and structural steel. The City of Thorold has a number of large and medium sized industries, with pulp and paper and automobile manufacturing being the largest employers.

The majority of the land in the two cities is within the Twelve Mile Creek watershed. The exceptions are three drainage areas which outlet to Lake Ontario, i.e. Spring Garden, Walkers and Beamer Creeks and as previously mentioned, the Welland Ship Canal.

There are two major sanitary drainage areas which terminate at sewage treatment plants near the shores of Lake Ontario (Port Dalhousie and Port Weller). The sewered areas serviced by the two plants consist of separated sanitary and storm sewer systems and, in the older portions of the cities, combined sewer systems. As a consequence of the older parts of the cities being served by combined sewers, significant amounts of surface runoff and other extraneous flows enter the trunk sanitary sewers (Figure 2.1). A design wet weather flow of approximately 2.5 times the peak dry weather flow is conveyed for treatment. Flows in excess of this amount are discharged through flow regulator chambers, untreated, to the receiving streams, either the Twelve Mile Creek or the Old Welland Canal.

2.3 Water Uses

Water is sold by the St. Lawrence Seaway Authority to a number of consumers along the Welland Ship Canal. The most significant client is Ontario Hydro which purchases a supply varying between 180 and 220 m^3/sec (6,400 and 7,800 cfs) for the DeCew Falls Generating Plant. The water is supplied to Lake Gibson which acts as a head pond for the generating plant.

The raw water supply for the DeCew Water Filtration Plant, which is operated by the Regional Municipality of Niagara, is also the Welland Ship Canal. The DeCew Water Plant serves the cities of Thorold and St. Catharines, the Town of Niagara-on-the-Lake and a portion of the Town of Lincoln, with an average annual consumption of approximately 1.4 m^3/sec (50 cfs). Other major users of the Welland Ship Canal water in the survey area include the Old Welland Canal to which water is supplied at the rate of 1.4 m^3/sec, the Ontario Paper Company (1.4 m^3/sec) and several smaller industries.

2.3.1 Recreation

In addition to scenic areas for picnicing, jogging and cross-country skiing, there are a variety of water-related activities within the study area. The Royal Canadian Henley Regatta on Martindale Pond (Twelve Mile Creek upstream of Lakeport Road) annually sponsors a world renowned rowing competition. A small crafts harbour is located at the mouth

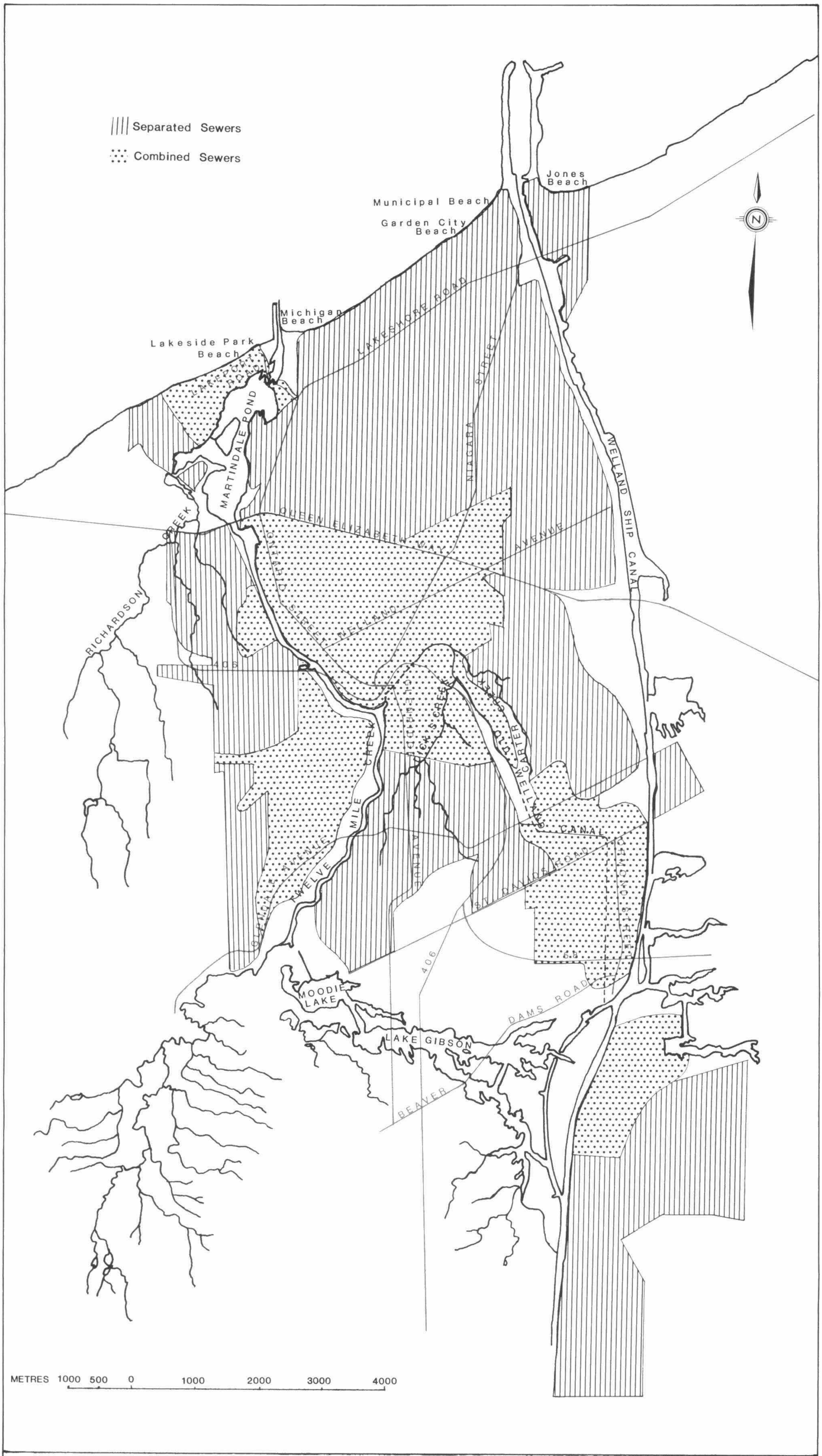


Figure 2.1 Location map of Combined and Separated Sewers

of Twelve Mile Creek and contains the Port Dalhousie Yacht Club, and the Snug Harbour Marina. Located adjacent to Jones Beach on the east side of the Welland Ship Canal is the St. Catharines Marina. In addition to these boating areas, St. Catharines has the five sandy beaches previously described.

2.3.2 Waste Assimilation

A number of industries operate their own waste disposal facilities and discharge their effluent into the storm drainage or surface water systems. Such discharges are regulated by the Ontario Ministry of the Environment. The industries are the following:

a) General Motors - Ontario Street (St. Catharines) plant, operates two oil separators to treat contaminated cooling water and drainage before discharge into Twelve Mile Creek.

b) General Motors - Foundry and Engine Plant located on Glendale Avenue (St. Catharines) treats its wastes in a lagoon situated at the northeast corner of their property. Discharge is to the Welland Ship Canal.

c) Ontario Paper - Located in Thorold, treats its pulping and paper-making wastes and discharges to the Old Welland Canal by an inverted syphon beneath the Welland Ship Canal.

d) A number of industries located along the Old Welland Canal obtain water from the Seaway Authority. Some of these firms treat their wastes and discharge the effluent into the Canal. These include Domtar Construction Materials, Fraser Inc., Kimberly-Clark, Domtar Paper and Hayes Dana.

e) Beaverwood Fiber - a paper mill, provides primary treatment for its waste which is then discharged to the Beaverdams Creek/Lake Gibson System.

Sanitary sewage is treated at two treatment plants. The Port Dalhousie plant and Port Weller plant both provide secondary treatment, phosphorous removal and disinfection by chlorination; however, chlorine is only used from May 15 to October 31. Treated effluent from the Port Dalhousie plant is discharged into Twelve Mile Creek at its mouth and from the Port Weller plant into the Welland Ship Canal also at its mouth. In both cases, the effluent mixes with the outgoing flow and is discharged into Lake Ontario through channels formed by breakwalls which were constructed for the Port Dalhousie and Port Weller Harbours. The rated capacity of the Port Dalhousie sewage treatment plant is 61,370 m^3/d (13.5 MIGD). When flows exceed 122,700 m^3/d (27 MIDG), the excess flow is diverted into Twelve Mile Creek. Port Weller is rated at a capacity of 37,500 m^3/d (8.3 MIGD); however, most hydraulic and all biological components can handle 56,250 m^3/d (12.4 MIGD). When flows exceed 56,250 m^3/d, the excess flow is diverted to the Welland Ship Canal.

2.3.3 Shipping

A significant feature of the water systems in Thorold and St. Catharines is the water supply from the Welland Ship Canal. The total flow of water entering the Canal at Port Colborne can be as high as 300 m^3/sec (10,600 cfs), with only approximately 10 to 15% being used for operating the locks(3). The difference of 99.5 m (326.5 ft) between the levels of Lake Ontario and Lake Erie is now overcome with eight locks and 43.4 km (27 miles) of channel in the fourth Welland Canal(5).

3.0 Field Investigations

Field investigations of combined sewer overflows and storm outfalls from the urban portion of the study area were carried out during May 1984 and August 1985. During the 1984 field work, with the assistance of Engineering staff of the City of St. Catharines, almost 60 outfalls and overflow structures to the Twelve Mile Creek were inspected during dry weather conditions (no precipitation for the previous 48 hours). These outfalls included the six paper mills and the Port Dalhousie sewage treatment plant. The majority of the outfalls inspected were part of the combined sewer system in the older portion of St. Catharines (Figure 2.1). Combined sewers contain both storm and sanitary flows. Therefore, an outlet is required when either the combined sewer capacity or the sewage treatment plant capacity is exceeded.

The 1985 field work included, with the assistance of City Engineering staff, the inspection of 41 sanitary, combined and storm manholes in the City of Thorold. Sewer inspections were conducted by examining combined sewer overflow structures and storm and sanitary manholes adjacent to the Old Welland Canal. Manhole inspections were necessary in Thorold due to the large flows in the Old Welland Canal and because the Canal is entirely enclosed.

The following two sections detail the findings of the two field investigations.

3.1 Field Work - 1984

The 1984 field investigations, during dry weather periods, located 9 storm sewer outfalls and 4 combined sewer overflow structures discharging sanitary wastewater. This information was forwarded to the City of St. Catharines Engineering Department on July 2, 1984, for corrective action. A summary of all problem sites and corrective measures completed by the City is presented in Table 3.1.

It was estimated that the total outflow from these overflows and storm sewers was approximately 60 litres per second. Sanitary sewage can be expected to contain up to 10 million coliform organisms per 100 ml. Therefore, these contributions represent a significant load to the Twelve Mile Creek system.

These problem sites were re-inspected prior to the July instream survey and only the 78" Centennial Park and Wellandvale sewers were still found to be discharging. However, the outflow had been reduced significantly in the Centennial Park sewer. The observed improvements were a result of increased cleaning and other remedial works carried out by the City. These two sewers were included in the July instream survey sampling program.

3.2 Field Work - 1985

The 1985 field investigation during dry weather periods located two storm sewer connections and one combined sewer overflow structure discharging sanitary wastewater. This information was forwarded to the City of Thorold Engineering Department for corrective action.

The two storm sewer connections that were discharging sanitary wastewater were located near the intersection of Lynden and Ormond Streets. Both of these connections discharged to the Old Welland Canal. The discharging combined sewer overflow structure was located on the east side of Pine Street between Albert and Ann Streets. This overflow structure was sealed with concrete at one time, however, it had deteriorated and partially collapsed. Combining all three sanitary discharges, it was estimated that approximately 30 litres/second of wastewater were being continuously discharged to the Old Welland Canal.

TABLE 3.1

LOCATION, PROBLEM AND CORRECTIVE MEASURES OF INADVERTANT SANITARY WASTEWATER DISCHARGES

	Site Location	Problem Description	Corrective Measure Taken
1.	Centennial Park Outfall	Dry Weather Flow Discharge & high bacterial counts	New design of overflow being completed.
2.	Grapeview Drive Outfall	High Bacteria Counts in Creek	Overflow has been blocked off.
3.	Carter Creek Outfall	Low weir level	Weir level raised.
4.	Wellandvale Outfall	Dry weather flow overflowing weir	Cleaned overflow weir of debris
5.	Renown Road at Ridley Rd.	Dry weather flow discharging to storm sewer	Overflow has been blocked off
6.	Renown Road at St. Paul Cres.	Dry weather flow overflowing weir	Work order issued to improve the hydraulics of the manhole.
7.	Salina Street Outfall	Connection Pipe blocked to trunk sewer	New overflow structure constructed.
8.	Riverview Boulevard Outfall	High bacteria counts in outfall waters	Illegal connections are responsible. Are evaluating cost sharing for corrective work.
9.	River Crest Drive Overflow	Very little freeboard in overflow structure	Operating as designed.
10.	Kent Street Overflow	Very little freeboard in overflow structure	Operating as designed.
11.	Glengarry at Glendale	Very little freeboard in overflow structure	Overflow structure improved.
12.	Rockcliff Road Outfall	Could not locate (located by City staff)	Operating satisfactorily.
13.	Carlton Street	Could not locate (located by City staff)	Operating satisfactorily.

TABLE 3.1 cont'd

LOCATION, PROBLEM AND CORRECTIVE MEASURES OF SANITARY WASTEWATER DISCHARGES

	Site Location	Problem Description	Corrective Measure Taken
14.	Moffat Street Outfall	Direct discharge to Old Welland Canal	New sewer to be constructed.
15.	Lakeport Road Outfall at Old Locks	Could not locate	No dry weather flow occurring.
16.	Lakeport Road Outfall at Harbour	Trash racks plugged	Trash racks cleared of debris and placed on routine maintenance schedule.

4.0 Bacteriological Water Quality

The instream survey design used the fecal coliform parameter as a bacteriological water quality indicator. Fecal coliform densities in water can be related to the presence of sewage and therefore to the risk of contracting a disease from pathogens which may be contained therein. Fecal coliforms are recognized as a standard indicator of bacteriological water quality for recreational use.

The fecal coliform group includes the genera Escherichia coli, Klebsiella, Enterobacter and Citrobacter. While all these organisms are found in animal and human wastes, Klebsiella, Enterobacter and Citrobacter are also found in the natural environment thus making it difficult to pinpoint their true source of origin. Escherichia coli (E. coli) has been shown to be a much more reliable indicator to detect fecal pollution from human wastes.

Six paper mills are located in the study area; five discharge to the Old Welland Canal while the sixth discharges to Lake Gibson. Klebsiella naturally comprises a large fraction of the bacteria found in the pulp and paper wastewaters and is not associated with fecal contamination but processed waste contamination. In addition to E. coli, Klebsiella and Pseudomonas aeruginosa were also analyzed in some of the surveys.

The health significance of Klebsiella has caused considerable debate in the past since only one of its five taxonomic groups, specifically K. pneumoniae sensu stricto is an opportunistic pathogen and only infects "high risk individuals"(7). However, its health significance in surface waters is unknown. Pseudomonas aeruginosa on the other hand is directly linked to infections in swimmers and bathers. This pathogen was sampled when appropriate sample allocation resources were available from the laboratory.

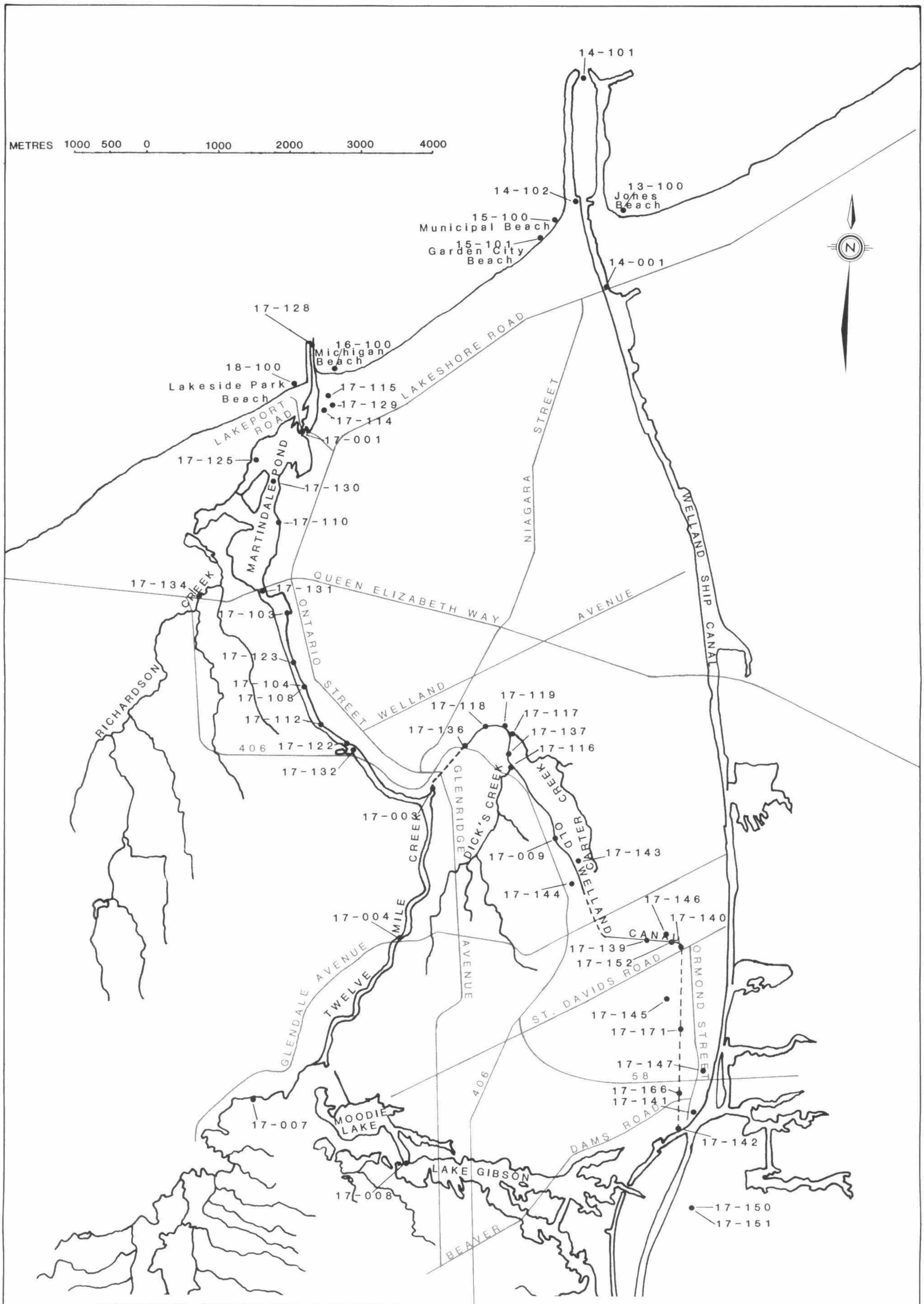
4.1 Instream Surveys 1984 - 1985

Four, three-day instream surveys were conducted during the two year period (two per year). Sampling stations (Figure 4.1) were visited at four hour intervals. Stream and effluent flows were measured or estimated on a regular basis wherever possible. Water samples were taken and kept on ice and transported twice daily to the MOE laboratory in Toronto for bacterial analysis.

4.1.1 July 9 - 12, 1984 Survey

The July 9 - 12, 1984, instream survey was the most intensive of the four studies. This survey was designed to evaluate the importance of all identified bacteria sources to the Twelve Mile Creek drainage system. Forty-seven stream and effluent sources were sampled, stream flows or discharges were measured or estimated and times of travel between instream sampling stations were determined. Mixing studies were carried out to identify appropriate sampling sites.

Water samples were analyzed for fecal coliforms, E. coli, Pseudomonas aeruginosa, dissolved oxygen, temperature and pH. Geometric means for fecal coliforms and Pseudomonas aeruginosa and arithmetic means for dissolved oxygen (D.O.), temperature, pH and flow are summarized in Table 4.1. Table 4.2 presents the maximum, minimum and median values for fecal coliforms. E. coli data have been deleted because of analytical problems (see Section 4.4).



06-0017-150-02	Beaverwood Fibers Clarifier Effluent
" " 17-151 "	Beaverwood Fibers Spill Pond Effluent
" " 17-008 "	Gibson Lake at Decew Road
" " 17-007 "	Twelve Mile Creek - First Street
" " 17-004 "	Twelve Mile Creek - Glendale Avenue
" " 17-132 "	Twelve Mile Creek - Fourth Avenue
" " 17-122 "	Wellandvale Avenue Sewer Outfall
" " 17-112 "	Kensington Place Sewer Outfall
" " 17-108 "	General Motors Cooling Water Effluent
" " 17-104 "	General Motors Relief Sewer
" " 17-123 "	Manchester Avenue Sewer Outfall
" " 17-103 "	Scott Street Sewer Outfall
" " 17-131 "	Twelve Mile Creek - Q.E.W. Bridge
" " 17-134 "	Richardson Creek
" " 17-110 "	Royal Henley Drive Sewer Outfall
" " 17-130 "	Martindale Pond - Centre
" " 17-125 "	Corbet Avenue Sewer Outfall
" " 17-001 "	Twelve Mile Creek - Lakeport Road
" " 17-129 "	Port Dalhousie S.T.P.
" " 17-115 "	McKenzie Drain North
" " 17-114 "	McKenzie Drain West
" " 17-128 "	Twelve Mile Creek - Mouth

06-0018-100-01	Lakeside Park Beach
" " 16-100 "	Michigan Beach
" " 15-101 "	Garden City Beach
" " 15-100 "	Municipal Beach
" " 13-100-02	Jones Beach

06-0017-142-02	Old Welland Canal - Intake
" " 17-141 "	Ontario Paper Final Effluent
" " 17-166 "	Old Welland Canal - Dock Road
" " 17-147 "	Domtar Construction Final Effluent
" " 17-171 "	Old Welland Canal - Beaver Dams Park
" " 17-145 "	Fraser Inc.
" " 17-140 "	Old Welland Canal - Townline Road
" " 17-152 "	Old Welland Canal - John Street
" " 17-146 "	Kimberly Clark Inc.
" " 17-139 "	Old Welland Canal - Ball Avenue
" " 17-144 "	Domtar Fine Papers Inc.
" " 17-143 "	Hayes Dana Inc.
" " 17-009 "	Old Welland Canal - Disher Street
" " 17-116 "	Dick's Creek
" " 17-137 "	Old Welland Canal - Westchester Avenue
" " 17-117 "	Carter Creek
" " 17-119 "	St. Catherines Hospital Sewer Outfall
" " 17-118 "	Centennial Park - 78" Sewer Outfall
" " 17-136 "	Old Welland Canal - Tricell Intake
" " 17-003 "	Old Welland Canal - Tricell Outlet

06-0014-001-02	Welland Ship Canal - Lakeshore Road
" " 14-102 "	Port Weller S.T.P.
" " 14-101 "	Welland Ship Canal - Mouth

Figure 4.1 Location map of Study Area's Monitoring Stations

TABLE 4.1

ST. CATHARINES OFF-BEACHES SURVEY DATA SUMMARY

JULY 9 - 11, 1984

Station Description	Geometric Mean		Arithmetic Mean				
	Organisms/100 ml Fecal Coliforms # of Samples	P. aeruginosa # of Samples	Estimated Flow m^3/s	Dissolved Oxygen mg/l	Temperature °C	pH Units	Fecal Coliform Load organisms/sec $x 10^8$
Old Welland Canal - Intake	51 - 4	10 - 1	1.4	7.57	19.5	8.24	0.0071
Ontario Paper Final Effluent	49,195 - 17	106 - 9	1.4	5.47	22.8	6.61	6.9
Domtar Construction Final Effluent	1,516,575 - 2	158 - 5	0.0099	4.10	25.1	7.08	1.5
Fraser Inc.	316 - 6	34 - 6	0.33	5.93	24.6	6.67	0.010
Old Welland Canal - John Street	201,351 - 15	120 - 9	3.1	4.78	22.0	6.94	62
Kimberly Clark Inc.	58 - 6	27 - 6	0.080	3.31	25.6	7.07	0.00046
Old Welland Canal-Ball Avenue	101,163 - 9	115 - 5	3.2	6.90	20.7	7.22	32
Domtar Fine Paper Inc.	192 - 6	70 - 6	0.12	5.25	26.2	7.13	0.0023
Hayes Dana Inc.	497 - 6	115 - 6	0.11	4.89	24.2	6.73	0.0055
Old Welland Canal-Disher Street	190,094 - 9	100 - 5	3.4	6.86	21.0	7.51	65
Dick's Creek	1,366 - 11	22 - 6	0.0028	5.12	19.5	7.56	0.00038
Old Welland Canal-Westchester Street	410,000 - 16	108 - 9	3.5	6.51	20.9	7.57	140
Carter Creek	5,390 - 11	73 - 6	0.031	7.72	19.8	7.65	0.017
St. Catharines Hospital Sewer Outfall	41 - 13	11 - 7	0.0020	7.53	21.0	7.91	0.0000082
Centennial Park - 78" Sewer Outfall	6,152,488 - 17	11,307 - 9	0.023	4.51	21.1	6.86	14
Old Welland Canal - Tricell Intake	373,309 - 9	143 - 5	3.5	3.90	20.9	7.37	131
Old Welland Canal - Tricell Outlet	262,770 - 16	191 - 8	3.5	3.92	20.9	7.52	92
Beaverwood Fiber Clarifier Effluent	189 - 5	53 - 5	0.0010	5.14	23.7	7.04	0.0000019
Beaverwood Fiber Spill Pond Effluent	3,956 - 5	125 - 5	0.0010	2.81	21.9	6.81	0.00040
Gibson Lake at Decew Road	20 - 4	10 - 1	200	7.71	19.0	8.23	0.40
Twelve Mile Creek-First Street	282 - 4	10 - 1	0.11	8.42	18.8	8.16	0.0031
Twelve Mile Creek-Glendale Avenue	32 - 17	13 - 9	200	7.94	19.6	8.23	0.64
Twelve Mile Creek-Fourth Avenue	4,410 - 17	12 - 9	200	7.56	19.4	8.19	89
Wellandvale Avenue Sewer Outfall	1,624 - 13	51 - 6	0.00090	8.61	16.6	7.98	0.00015

TABLE 4.1 (cont.)

ST. CATHARINES OFF-BEACHES SURVEY DATA SUMMARY

JULY 9 - 11, 1984

Station Description	Geometric Mean Organisms/100 ml Fecal Coliforms # of Samples	Geometric Mean Organisms/100 ml P.aeruginosa # of Samples	Arithmetic Mean Estimated Flow m^3/s	Arithmetic Mean Dissolved Oxygen mg/l	Arithmetic Mean Temperature °C	Arithmetic Mean pH Units	Fecal Coliform Load organisms/sec x 10^8
Kensington Place Sewer Outfall	68 - 7	29 - 6	0.028	7.26	27.7	8.21	0.00019
General Motors Cooling Water Effluent	30 - 8	24 - 6	0.0085	7,82	23.5	8.11	0.000026
General Motors Relief Sewer	225 - 8	11 - 6	0.028	7.37	27.6	8.10	0.00063
Manchester Avenue Sewer Outfall	23,599 - 8	73 - 6	0.014	7.56	26.0	8.33	0.033
Scott Street Sewer Outfall	10,612 - 6	818 - 5	0.000010	7.56	19.7	8.43	0.000011
Twelve Mile Creek-QEW Bridge	3,410 - 8	12 - 7	200	8.26	18.0	8.28	68
Richardson Creek	206 - 7	13 - 3	0.0015	5.82	15.3	8.05	0.000031
Royal Henley Drive Sewer Outfall	2,371 - 4	703 - 3	0.000020	8.58	19.7	8.39	0.0000047
Martindale Pond-Centre	2,214 - 7	14 - 6	200	8.27	17.4	7.78	44
Corbett Avenue Sewer Outfall	114 - 6	17 - 5	0.0017	7.19	19.4	7.89	0.000019
Twelve Mile Creek - Lakeport Road	3,467 - 10	24 - 5	200	7.91	19.5	8.15	69
Port Dalhousie STP	47 - 16	22 - 9	0.35	4.79	20.7	7.00	0.0016
McKenzie Drain North	5,730 - 7	230 - 3	0.0027	6.36	18.1	7.84	0.0015
McKenzie Drain West	4,074 - 7	393 - 3	0.00030	6.84	18.9	7.59	0.00012
Twelve Mile Creek Mouth	1,014 - 4	18 - 4	200	7.71	20.1	7.82	20
Welland Ship Canal - Lakeshore Road	17 - 4	10 - 1	-	8.63	21.2	8.03	-
Port Weller STP	4,206 - 17	135 - 9	0.33	4.30	19.3	7.17	0.014
Welland Ship Canal-Mouth	40 - 6	10 - 4	-	8.33	19.8	8.27	-
Lakeside Park Beach	134 - 2	14 - 2	-	-	17.0	-	-
Michigan Beach	214 - 2	14 - 2	-	-	17.0	-	-
Garden City Beach	1,517 - 2	45 - 2	-	-	17.0	-	-
Municipal Beach	509 - 2	45 - 2	-	-	17.0	-	-
Jones Beach	20 - 2	32 - 2	-	-	17.0	-	-

TABLE 4.2

ST. CATHARINES OFF-BEACHES SURVEY STATISTICS SUMMARY, JULY 9-11, 1984

Station Description	Fecal Coliform Organisms/100 ml		
	Minimum	Maximum	Median
Old Welland Canal-Intake	10	430	50
Ontario Paper Final Effluent	4,200	270,000	80,000
Domtar Construction Final Effluent	100,000	23,000,000	11,450,000
Fraser Inc.	20	10,000	300
Old Welland Canal-John Street	10,000	1,116,000	240,000
Kimberly Clark Inc.	20	100	100
Old Welland Canal-Ball Avenue	1,000	1,000,000	130,000
Domtar Fine Paper Inc.	60	1,400	100
Hayes Dana Inc.	120	3,000	390
Old Welland Canal-Disher St.	8,000	1,300,000	300,000
Dick's Creek	600	2,400	1,240
Old Welland Canal-Westchester Avenue	80,000	16,000,000	580,000
Carter Creek	1,000	20,000	6,800
St. Catharines Hospital Sewer Outfall	10	860	20
Centennial Park-78" Sewer Outfall	1,190,000	46,000,000	5,000,000
Old Welland Canal-Tricell Intake	30,000	7,000,000	410,000
Old Welland Canal-Tricell Outlet	20,000	2,400,000	365,000
Beaverwood Fiber Clarifier Effluent	40	1,000	100
Beaverwood Fiber Spill Pond Effluent	1,000	7,500	4,500
Gibson Lake at Decew Road	10	40	20
Twelve Mile Creek-First Street	160	400	320
Twelve MIle Creek-Glendale Avnue	10	100	30
Twelve Mile Creek-Fourth Avenue	300	33,000	7,300
Wellandvale Avenue Sewer Outfall	580	6,000	1,250
Kensington Place Sewer Outfall	20	200	65
General Motors Cooling Water Effluent	10	80	45
General Motors Relief Sewer	40	1,600	120
Manchester Avenue Sewer Outfall	15,000	56,000	25,000
Scott Street Sewer Outfall	2,680	50,000	11,000
Twelve Mile Creek-QEW Bridge	1,200	15,000	3,300
Richardson Creek	100	340	240
Royal Henley Drive Sewer Outfall	660	14,700	1,810
Martindale Pond-Centre	100	15,000	2,200
Corbett Avenue Sewer Outfall	10	590	135
Twelve Mile Creek-Lakeport Road	200	24,000	8,600
Port Dalhousie STP	10	1,600	60
McKenzie Drain North	1,480	36,000	4,300
McKenzie Drain West	690	14,000	5,800
Twelve Mile Creek-Mouth	100	6,600	1,400
Welland Ship Canal-Lakeshore Road	10	20	20
Port Weller STP	90	111,000	15,000
Welland Ship Canal-Mouth	20	100	45
Lakeside Park Beach	100	180	140
Michigan Beach	20	2,300	1,160
Garden City Beach	100	23,000	11,550
Municipal Beach	370	700	535
Jones Beach	20	20	20

No significant fluctuations were observed for dissolved oxygen, temperature or pH except for the normal diurnal changes. Pulp and paper mill effluent generally had lower dissolved oxygen and higher temperatures than storm sewer outfalls, creeks, the Old Welland Canal and Twelve Mile Creek.

The geometric mean of bacterial levels in the Old Welland Canal at the Tricell Outlet was 262,770 org/100 ml for fecal coliforms. The sources with loadings high enough to cause these levels were Centennial Park sewer outfall, Ontario Paper and Domtar Construction.

Five paper companies discharge to the Old Welland Canal. Two of those, the Ontario Paper Company and Domtar Construction, had the second and the third highest bacterial levels and loads of all bacterial sources measured (Centennial Park sewer was the largest). The Pseudomonas aeruginosa levels were also high, in excess of 100 org./100 ml.

Pseudomonas aeruginosa analyses provided by the laboratory were generally approximations of magnitude and should be viewed as such rather than as firm numbers. However, the presence of this organism in any number is important as it is itself a pathogen and not just an indicator organism (Table 4.1).

The three remaining paper mills that discharge to the Old Welland Canal are Fraser, Kimberly Clark and Domtar Fine Papers. Fecal coliform geometric means for these plant effluents were 316, 58 and 192 org./100 ml with Pseudomonas aeruginosa levels of 34, 27 and 70 org./100 ml respectively.

Discharges from Beaverwood Fiber to Lake Gibson come from two sources, the clarifier and the spill pond effluent. The clarifier effluent had levels of 189 and 53 org./100 ml of fecal coliforms and Pseudomonas aeruginosa respectively. However, the spill pond effluent contained 3,956 fecal coliform org./100 ml and 125 org./100 ml Pseudomonas aeruginosa. The flow from this source is small and is likely to have little impact on Lake Gibson and negligible impact on the beaches because of the large dilution.

In addition to the pulp and paper effluents, two other industrial effluents were sampled. Yard drainage from the Hayes-Dana plant showed fecal coliform levels of 497 org./100 ml and Pseudomonas aeruginosa levels of 115 org./ 100 ml.

The other industrial source is the General Motors plant which discharges to Twelve Mile Creek. This discharge is primarily made up of cooling water, part of which is discharged to the Kensington Place sewer. The remainder is discharged directly to Twelve Mile Creek. Fecal coliform levels of 68 org./100 ml were found to be within acceptable limits, while Pseudomonas aeruginosa was 25 org./100 ml.

All 16 problem areas identified in Table 3.1 were re-visited and examined for discharge. Four storm sewer outfalls were found to be still active and were sampled during this survey. It was found that only two of the overflows were seriously contaminated, the 78" Centennial Park sewer and Wellandvale combined sewer discharge.

The Centennial Park sewer had the highest loads during the study even though its average discharge was only 0.023 m^3/s (0.81 cfs). Geometric mean levels of fecal coliforms and Pseudomonas aeruginosa were approximately 6,000,000 and 11,000 org./100 ml respectively. These were the highest found anywhere during the survey and represent a significant source of contamination. The Wellandvale sewer showed a much lower level of fecal coliforms at 1,624 org./100 ml. The Corbett Avenue and the St. Catharines Hospital sewer outfalls showed lower levels of fecal coliform (FC) and Pseudomonas aeruginosa (PsA).

Three additional sewers were found to be discharging to Twelve Mile Creek. All three showed elevated bacterial levels. The Royal Henley Blvd. (2,371 org./100 ml FC, 703 org./100 ml PsA) and Scott Street (10,612 org./100 ml FC, 818 org./100 ml PsA) storm sewers had very low flows and did not impact greatly on the creek. The Manchester Avenue storm sewer (23,599 org./100 ml FC, 73 org./100 ml PsA) had a much larger discharge, 0.014 m^3/s (0.5 cfs) representing a more significant load.

Four small streams, McKenzie drain, Dick's Creek, Carter Creek and Richardson's Creek flow into Twelve Mile Creek or the Old Welland Canal. Richardson's Creek (206 org./100 ml FC, 13 org./100 ml PsA) contained only low levels of bacteria likely resulting from rural land runoff. The three remaining creeks including both branches of McKenzie drain showed elevated bacterial levels indicating fecal contamination. However, these creeks had small flows and thus had a small impact on the system.

The Port Dalhousie Sewage Treatment Plant effluent had very good bacterial quality during this study (47 org./100 ml FC, 22 org./100 ml PsA). Although its effluent flow averaged 30,000 m^3/d during the study, it had little impact on Twelve Mile Creek. The Port Weller Sewage Treatment Plant effluent discharged higher levels of bacteria. Geometric means of samples taken were 4,206 fecal coliform and 135 Pseudomonas aeruginosa org./100 ml. Fecal coliform levels were measured as high as 111,000 org./100 ml. The Welland Ship Canal mouth which receives this effluent indicated very little impact (40 org./100 ml FC) due to the high dilution flows (36 to 45 cms).

4.1.2 August 28 - 30, 1984 Survey

The main purpose of this survey was to evaluate the impact of a rainfall event with regard to fecal coliforms in the Twelve Mile Creek system (wet weather survey). The survey was timed to coincide with predicted summer storms. The number of stations sampled during this survey were reduced to allow concentrated sampling of the catchments in St. Catharines. The data collected during August 28 to 30 are summarized in Tables 4.3 and 4.4. The survey failed in its main task because the storm commenced during the last 1 1/2 hours of the survey which prevented adequate sampling. The rainfall intensity caused three flow measuring installations to be knocked out, resulting in loss of flow data.

Although the impact of the storm could not be properly quantified, the 13 mm of rain that fell, mostly in about 1/2 hour, caused dramatic flow increases in the small streams that act as storm channels. Also, most sewer outfalls were observed to be running nearly full. Storm inflows to both the Port Weller and Port Dalhousie sewage treatment plants caused significant increases for short periods.

The fecal coliform levels at all instream stations during the dry weather portion of the survey were lower than those observed in the July survey except in Twelve Mile Creek at Glendale Avenue and Twelve Mile Creek at its mouth (Figures 4.2 and 4.3). These lower levels correspond to substantial decreases in bacterial discharges measured at Ontario Paper and Centennial Park outfalls.

TABLE 4.3

ST. CATHARINES OFF-BEACHES SURVEY DATA SUMMARY

AUGUST 28 - 30, 1984

Station Description	Geometric Mean				Arithmetic Mean				Load organisms/sec x 10^8	
	Organisms/100 ml Fecal Coliforms	# of Samples	Klebsiella	# of Samples	Estimated Flow m^3/s	Dissolved Oxygen mg/l	Temperature °C	pH Units	Fecal	Klebsiella
Old Welland Canal-Intake	36	3	283	2	1.4	8.02	22.4	8.69	0.0050	0.040
Ontario Paper Final Effluent	11,920	8	50,575	5	1.6	5.90	30.6	7.27	19	81
Old Welland Canal-John Street	10,096	7	94,211	6	3.0	6.21	27.5	7.64	3.0	28
Old Welland Canal-Westchester Avenue	5,316	7	-		3.6	6.98	27.9	8.37	1.9	-
Carter Creek	15,544	15	-		0.099	7.61	21.9	8.17	0.15	-
St. Catharines Hospital Sewer Outfall	1,800	1	-		0.0020	-	-	-	0.0036	-
Centennial Park-78" Sewer Outfall	375,538	14	3,916,663	10	0.052	4.67	28.1	7.63	2.0	20
Old Welland Canal-Tricell Outlet	11,698	10	1,080,000	6	3.7	5.01	26.1	7.88	4.3	400
Twelve Mile Creek - Glendale Avenue	306	2	-		190	8.40	22.5	8.40	5.8	-
Twelve Mile Creek-Fourth Avenue	1,216	6	-		190	8.54	23.2	8.32	23	-
Wellandvale Sewer Outfall	9,457	10	-		0.0010	8.55	19.9	7.96	0.00095	-
Manchester Avenue Sewer Outfall	9,830	6	-		0.014	7.40	24.9	8.07	0.014	-
Scott Street Sewer Outfall	39,000	1	-		0.0010	-	-	-	0.0039	-
Twelve MIle Creek - QEW Bridge	2,166	6	-		190	8.26	22.5	8.20	41	-
Royal Henley Drive Sewer Outfall	3,103	10	-		0.00010	8.17	20.3	7.93	0.0000031	-
Twelve Mile Creek - Lakeport Road	980	5	27,023	3	190	5.32	24.1	8.47	19	510
Port Dalhousie STP	109	11	-		0.35	4.64	23.9	7.10	0.0038	-
McKenzie Drain North	3,442	13	-		0.0040	8.82	22.2	7.76	0.0014	-
Twelve Mile Creek-Mouth	3,513	6	-		190	8.28	24.2	8.00	67	-
Welland Ship Canal-Lakeshore Road	92	3	-		-	8.90	22.5	8.18	-	-
Port Weller STP	20,028	13	-		0.33	4.40	23.0	7.24	0.66	-
Welland Ship Canal-Mouth	32	7	-		-	8.15	24.7	7.90	-	-
Lakeside Park Beach	70	1	-		-	-	24.0	-	-	-
Michigan Beach	1,340	1	4,800	1	-	-	24.0	-	-	-
Garden City Beach	1,040	1	-		-	-	24.0	-	-	-
Municipal Beach	3,900	1	-		-	-	24.0	-	-	-
Jones Beach	20	1	60	1	-	-	24.0	-	-	-

TABLE 4.4

ST. CATHARINES OFF-BEACHES SURVEY STATISTICS SUMMARY, AUGUST 28 - 30, 1984

Station Description	Fecal Coliform Organisms/100 ml			
	Minimum	Maximum	Median	
Old Welland Canal-Intake	10	160	30	
Ontario Paper Final Effluent	1,000	230,000	11,550	
Old Welland Canal-John Street	100	120,000	10,000	
Old Welland Canal-Westchester Avenue	400	10,000	10,000	
Carter Creek	1,600	67,000	15,000	
St. Catharines Hospital Sewer Outafll	1,800	1,800	1,800	*only one valve
Centennial Park-78" Sewer Outfall	500	150 x 10^5	535,000	
Old Welland Canal-Tricell Outlet	1,000	200,000	10,000	
Twelve Mile Creek-Glendale Avenue	80	1,120	625	only two valves
Twelve Mile Creek-Fourth Avenue	300	15,000	900	
Wellandvale Sewer Outfall	170	200,000	7,950	
Manchester Avenue Sewer Outfall	2,800	47,000	10,900	
Scott Street Sewer Outfall	39,000	39,000	39,000	one valve
Twelve Mile Creek-QEW Bridge	300	30,000	2,250	
Royal Henley Drive Sewer Outfall	900	14,000	3,150	
Twelve Mile Creek-Lakeport Road	100	7,900	1,700	
Port Dalhousie STP	10	295,000	20	
McKenzie Drain North	100	18,000	5,100	
Welland Ship Canal-Lakeshore Road	20	240	160	
Port Weller STP	100	220,000	110,000	
Twelve Mile Creek-Mouth	1,000	15,000	3,250	
Welland Ship Canal-Mouth	10	440	20	
Lakeside Park Beach	70	70	70	one valve
Michigan Beach	1,340	1,340	1,340	one valve
Garden City Beach	1,040	1,040	1,040	one valve
Municipal Beach	3,900	3,900	3,900	one valve
Jones Beach	20	20	20	one valve

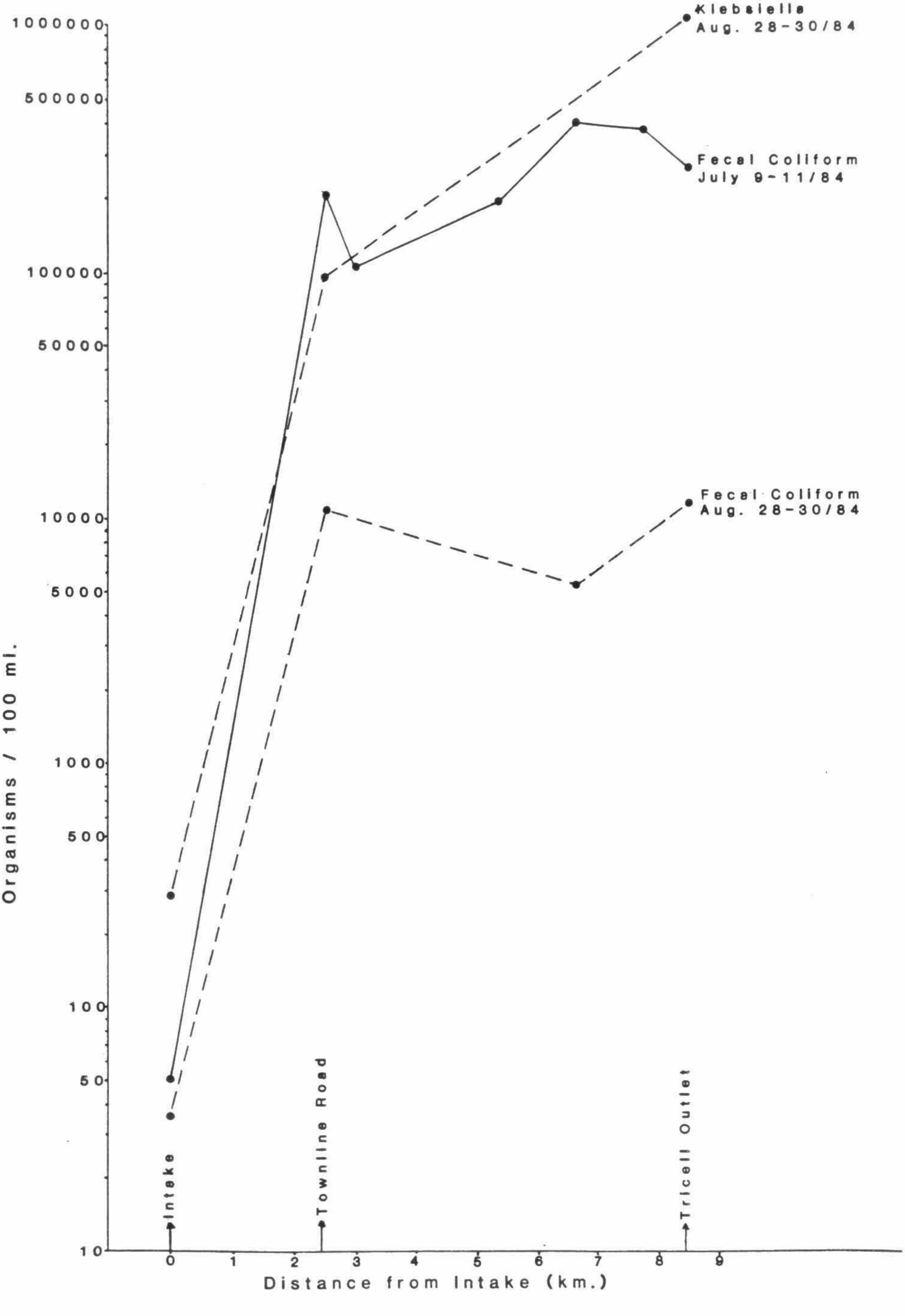


Figure 4.2: Bacterial Levels in Old Welland Canal – 1984

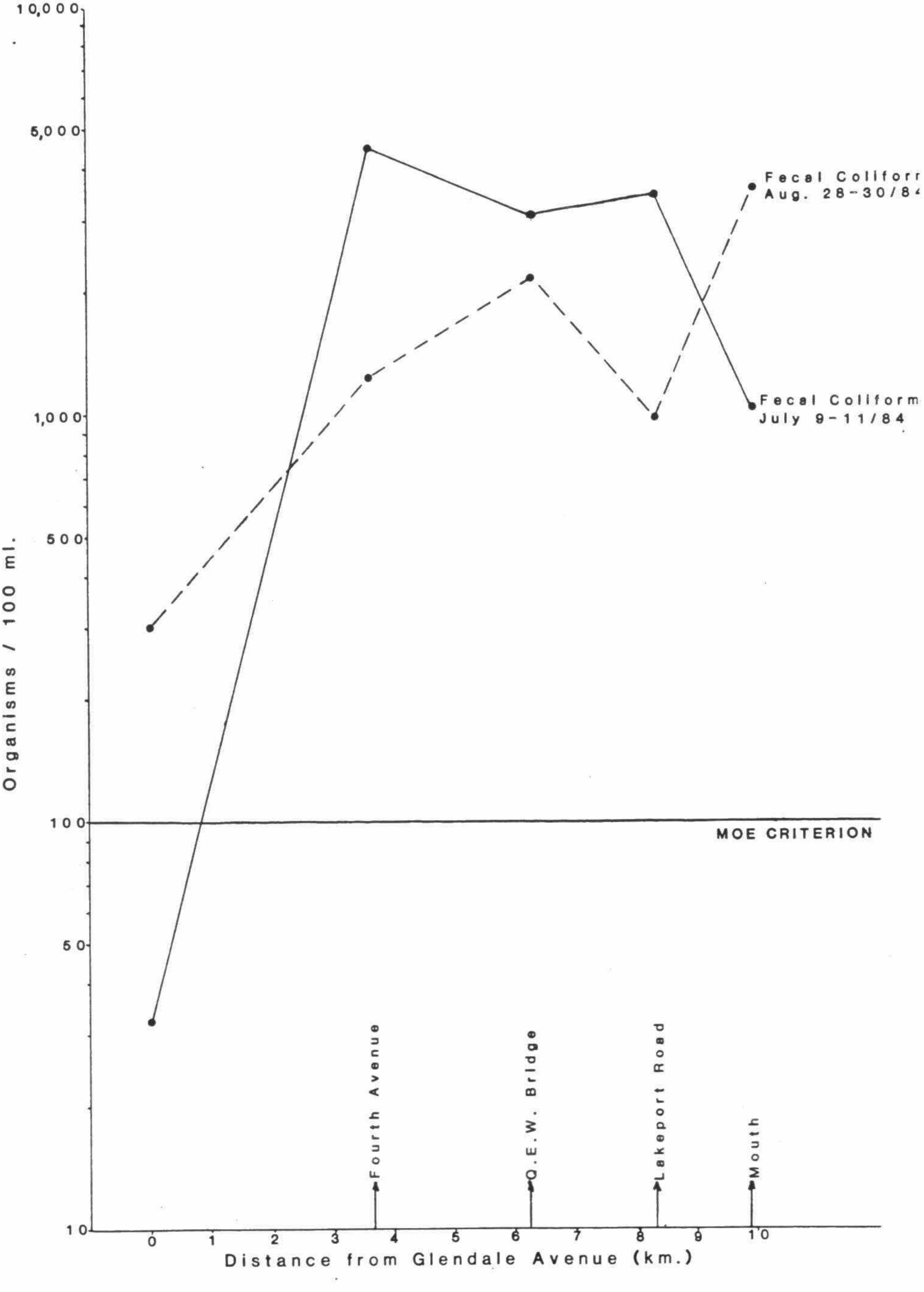


Figure 4.3: Bacterial Levels in Twelve Mile Creek – 1984

Samples from several stations were analyzed for Klebsiella sp. during this study. The observed levels of these organisms were higher than the corresponding fecal coliform concentrations (Figure 4.2). Although Klebsiella is part of the fecal coliform group, its levels may be higher due to the difference in test procedures and its association with pulp and paper wastes. The test for Klebsiella is carried out at a much lower incubation temperature which is far more favourable for its growth than is the fecal coliform test. The individual strains were not identified and the health significance of the observed organisms is not known. These results did show, however, that the Old Welland Canal is a favourable habitat for Klebsiella sp. and this organism likely comprises a considerable portion of the bacterial colonies found in the fecal coliform tests from the samples collected during this study, especially from the Old Welland Canal.

4.1.3 August 12 - 15, 1985 Survey

The August 12 - 15, 1985 survey was designed to identify which effluents have the most impact on bacterial contamination of the Old Welland Canal and Twelve Mile Creek. Samples along the Old Welland Canal were taken at points of discharge of five effluents and at six instream stations. In Twelve Mile Creek six instream stations and four effluents were sampled, including the Port Dalhousie sewage treatment plant effluent. The Welland Ship Canal at Lakeshore Road and the effluent of the Port Weller sewage treatment plant were also sampled. Each of the five beaches were sampled near shore at a 1 metre depth and by boat 150 m offshore. Water samples for bacterial analysis, water temperature, pH and dissolved oxygen readings were taken at each station.

The results shown in Tables 4.5 and 4.6 are for dry weather conditions which prevailed during the first three sampling days. In the early morning of August 15, a storm front

TABLE 4.5
ST. CATHARINES OFF-BEACHES SURVEY DATA SUMMARY
AUGUST 12 - 15, 1985

	Geometric Mean	Arithmetic Mean				
Station Description	Organisms/100 ml Fecal Coliforms - # of Samples	Estimated Flow m^3/s	Dissolved Oxygen mg/l	Temperature °C	pH Units	Fecal Coliform Load organisms/sec x 10^8
Old Welland Canal - Intake	1,489 - 14	1.4	8.4	23.6	8.0	0.21
Ontario Paper Final Effluent	234,095 - 17	1.4	5.1	32.4	6.5	33
Old Welland Canal-Dock Road	371,306 - 13	2.9	6.5	28.8	6.9	110
Domtar Construction Final Effluent	22,254 - 15	0.0080	4.8	34.1	7.4	0.018
Old Welland Canal Beaver Dams Park	542,143 - 14	2.9	5.9	27.9	7.2	160
Old Welland Canal-John Street	1,366,608 - 15	3.2	7.0	28.4	7.3	440
Dick's Creek	1,276 - 6	0.073	6.5	24.3	7.7	0.0093
Old Welland Canal-Westchester Avenue	1,595,873 - 15	3.6	6.5	26.6	7.4	570
Carter Creek	2,504,126 - 8	0.088	7.9	24.2	7.8	22
Centennial Park-78" Sewer Outfall	1,223 - 6	0.0080	6.7	30.2	8.0	0.00098
Old Welland Canal-Tricell Outlet	2,355,745 - 15	3.7	5.2	27.6	7.3	870
Twelve Mile Creek-Glendale Avenue	1,014 - 15	180	8.8	23.3	8.1	18
Twelve Mile Creek-Fourth Avenue	26,297 - 15	180	8.6	23.4	8.0	470
Kensington Avenue South	9,995 - 9	0.030	7.4	31.5	8.3	0.030
Manchester Avenue South	25,179 - 9	0.010	7.5	30.9	8.4	0.025
Twelve Mile Creek-QEW	40,561 - 9	180	9.0	23.7	8.4	730
Martindale Pond-Centre	40,332 - 9	180	8.8	24.0	8.4	730
Twelve Mile Creek-Lakeport Road	50,151 - 15	180	8.3	23.2	8.0	900
Port Dalhousie STP	115 - 8	0.35	5.7	23.8	7.1	0.0040
McKenzie Drain North	344 - 7	0.0040	11.3	25.9	8.0	0.00014
Twelve Mile Creek-Mouth	32,844 - 7	180	-	-	-	590
Welland Ship Canal-Lakeshore Road	30 - 9	-	9.7	22.8	8.2	-
Port Weller STP	12,488 - 8	0.33	4.5	21.9	7.0	0.41
Welland Ship Canal- Mouth	42 - 8	-	-	-	-	-

TABLE 4.5 Cont'd)
ST. CATHARINES OFF-BEACHES SURVEY DATA SUMMARY
AUGUST 12 - 15, 1985

Station Description	Geometric Mean Organisms/100 ml Fecal Coliform - # of Samples	Arithmetic Mean Estimated Flow m^3/s	Dissolved Oxygen mg/l	Temperature °C	pH Units	Fecal Coliform Load organisms/sec x 10^8
Lakeside Park Beach	553 - 9	-	10.5	22.2	8.1	-
Michigan Beach	4,248 - 7	-	9.5	21.7	8.1	-
Garden City Beach	500 - 9	-	9.7	21.7	8.1	-
Municipal Beach	181 - 8	-	10.1	21.1	8.2	-
Jones Beach	243 - 9	-	7.2	21.6	7.9	-
Lakeside Park Beach-Lake	99 - 7	-	-	-	-	-
Michigan Beach-Lake	2,799 - 4	-	-	-	-	-
Garden City Beach-Lake	639 - 8	-	-	-	-	-
Municipal Beach-Lake	379 - 7	-	-	-	-	-
Jones Beach-Lake	49 - 8	-	-	-	-	-

TABLE 4.6

ST. CATHARINES OFF-BEACHES SURVEY STATISTICS SUMMARY, AUGUST 12-15, 1985

Station Description	Fecal Coliform Organisms/100 ml Minimum	 Maximum	 Median
Old Welland Canal-Intake	120	6,000	1,350
Ontario Paper Final Effluent	20,000	1,540,000	270,000
Old Welland Canal-Dock Road	10,000	2,000,000	320,000
Domtar Construction Final Effluent	1,000	4,000,000	14,000
Old Welland Canal Beaver Dams Park	800	4,000,000	820,000
Old Welland Canal-John Street	10,000	6,300,000	1,600,000
Dick's Creek	640	34,000	1,500
Old Welland Canal-Westchester Avenue	110,000	4,000,000	1,550,000
Carter Creek	2,000	360,000,000	2,650,000
Centennial Park-78"Sewer Outfall	78	460,000	10,400
Old Welland Canal-Tricell Outlet	150,000	6,000,000	2,400,000
Twelve Mile Creek-Glendale Avenue	24	6,900	1,100
Twelve Mile Creek-Fourth Avenue	1,500	93,000	32,000
Kensington Avenue South	2,000	43,000	10,000
Manchester Avenue South	4,200	340,000	30,000
Twelve Mile Creek-QEW Bridge	7,000	81,000	48,000
Martindale Pond-Centre	6,600	770,000	53,000
Twelve Mile Creek-Lakeport Road	3,000	1,000,000	43,000
Port Dalhousie STP	2	280,000	136
McKenzie Drain North	70	23,000	700
Twelve Mile Creek-Mouth	6,000	76,000	43,000
Welland Ship Canal-Lakeshore Road	8	110	32
Port Weller STP	2	1,200,000	215,000
Welland Ship Canal-Mouth	12	410	41
Lakeside Park Beach	22	13,000	760
Michigan Beach	470	30,000	3,400
Jones Beach	40	720	300
Garden City Beach	12	130,000	52
Municipal Beach	12	20,000	45
Lakeside Park Beach-Lake	2	9,800	260
Michigan Beach-Lake	480	9,800	5,100
Garden City Beach-Lake	12	11,400	1,750
Municipal Beach-Lake	10	15,000	500
Jones Beach-Lake	18	150	40

passed over St. Catharines, resulting in four hours of rain. The geometric mean of bacterial concentrations from samples during this rain event are reported in Table 4.7.

Results presented in Table 4.5 show that high water temperatures and low dissolved oxygen values were recorded at stations along the Old Welland Canal. The origin of these values may be traced to two point sources, Ontario Paper and Domtar Construction final effluents. The 78" Centennial Park sewer also showed elevated water temperature, but the dry weather outflow from this source was negligible, i.e. not having any effect on the canal water temperature.

Levels of fecal coliform bacteria were highest at stations along the Old Welland Canal. Considering a background geometric mean of 1489 org./100 ml at the canal intake, the downstream levels point to the major sources of contaminants being Ontario Paper final effluent with geometric mean concentrations of 234,095 org./100 ml and Carter Creek with 2,504,126 org./100 ml. These results plotted in Figure 4.4 show the impact of Ontario Paper and Carter Creek on concentrations of fecal coliforms.

Results of fecal coliform levels in Twelve Mile Creek show relatively high concentrations of bacteria for all stations sampled (Table 4.5 and 4.6). Background values at Glendale Avenue were unexpectedly high, ranging between 24 and 6,900 org./100 ml (geometric mean 1,014 org./100 ml). This indicates that some unknown inputs exist and need to be identified along the upper reaches of Twelve Mile Creek or in the Welland Ship Canal. As shown in Figure 4.5, fecal coliform concentrations downstream from Glendale increase rapidly up to a geometric mean of 26,297 org./100 ml at

TABLE 4.7

ST. CATHARINES OFF-BEACHES SURVEY DATA SUMMARY, AUGUST 15, 1985
(WET WEATHER)

Station Description	Geometric Mean Organisms/100 ml Fecal
Old Welland Canal-Intake	600
Ontario Paper Final Effluent	-
Old Welland Canal-Dock Road	50,000
Domtar Construction Final Effluent	4,000,000
Old Welland Canal Beaver Dams Park	90,000
Old Welland Canal-John Street	100,000
Dick's Creek	34,000
Old Welland Canal-Westchester Avenue	-
Carter Creek	334,716
Centennial Park-78"Sewer Outfall	93,754
Old Welland Canal-Tricell Outlet	2,400,000
Twelve Mile Creek-Glendale Avenue	3,500
Twelve Mile Creek-Fourth Avenue	10,000
Kensington Avenue South	-
Manchester Avenue South	-
Twelve Mile Creek-QEW Bridge	-
Martindale Pond-Centre	-
Twelve Mile Creek-Lakeport Road	16,000
Port Dalhousie STP	280,000
McKenzie Drain North	18,290
Twelve Mile Creek-Mouth	36,000
Welland Ship Canal-Lakeshore Road	44
Port Weller STP	310,000
Welland Ship Canal-Mouth	50
Lakeside Park Beach	40
Michigan Beach	3,100
Garden City Beach	24,000
Municipal Beach	20,000
Jones Beach	400
Lakeside Park Beach-Lake	40
Michigan Beach-Lake	8,700
Garden City Beach-Lake	2,000
Municipal Beach-Lake	11,000
Jones Beach-Lake	40

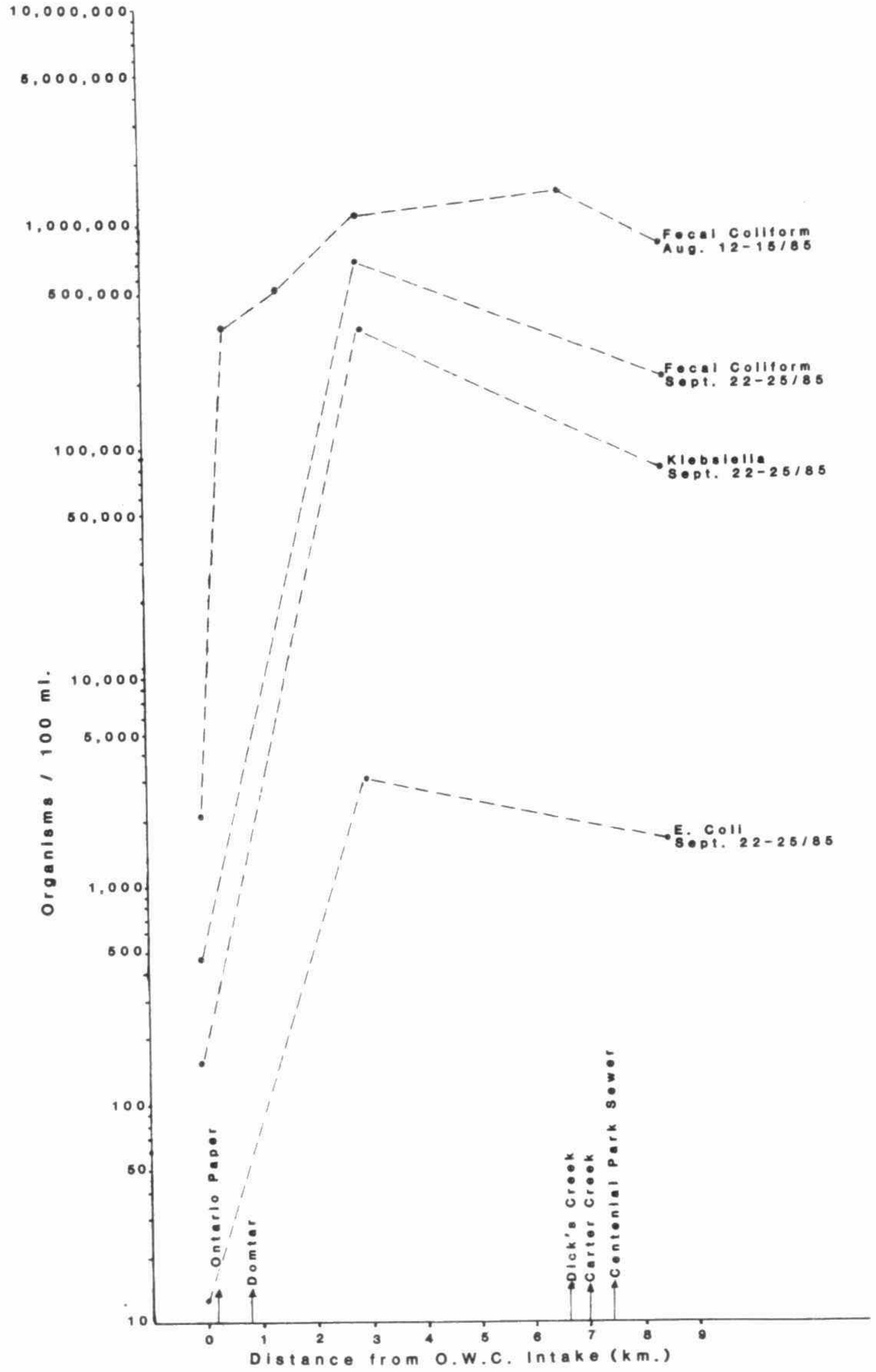


Figure 4.4 : Bacterial Levels in Old Welland Canal - 1985

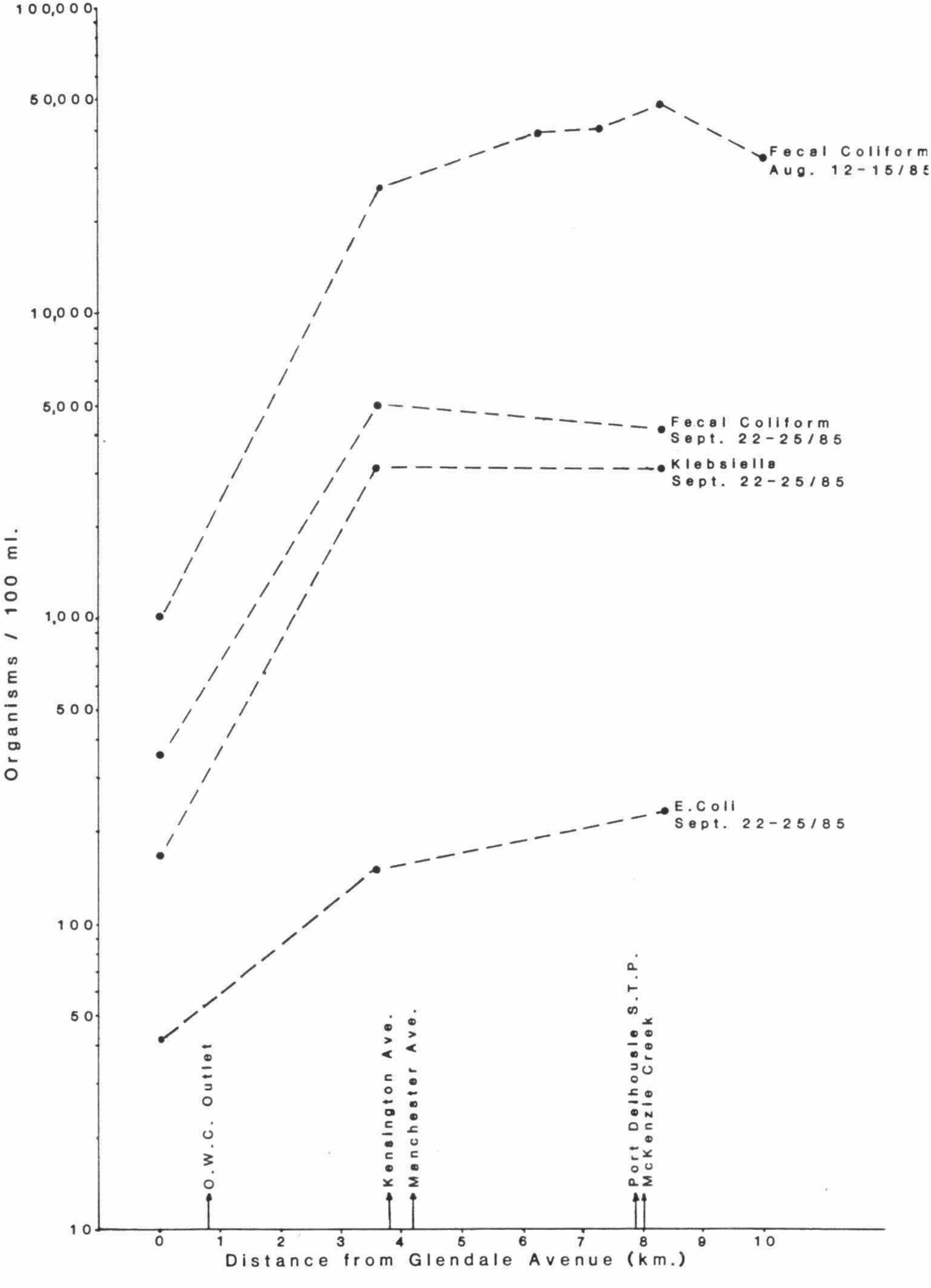


Figure 4.5: Bacterial Levels in Twelve Mile Creek - 1985

Fourth Avenue. The only major known input into the Creek between these two points is the Old Welland Canal which, as shown at the Tricell Outlet contributes 2,355,745 org./100 ml (range 150,000 to 6,000,000 org./100 ml, Table 4.6). The remaining four sources of inputs identified in early surveys in the remaining 8 km segment of Twelve Mile Creek contribute relatively little to instream bacterial loads. In total, these inputs into Twelve Mile Creek elevate the bacterial concentration to nearly 33,000 org./100 ml as measured at the mouth.

It is significant to note that the Port Dalhousie sewage treatment plant effluent contributes only a small input into Twelve Mile Creek (geometric mean 115 org./100 ml) and therefore would have relatively little impact on the bacterial load to the beaches. By contrast, Port Weller sewage treatment plant contributes approximately 12,488 org./100 ml to the Welland Ship Canal; but due to the large dilution factor of canal water, its impact on the receiving watercourse, as measured at the Welland Ship Canal mouth (42 org./100 ml, Table 4.5), is relatively negligible.

4.1.4 September 22 - 25, 1985 Survey

The less intense survey of September 22 - 25, 1985 was designed to determine levels of E. coli using mTEC-IG, fecal coliforms using mTEC and Klebsiella using mK laboratory analysis growth mediums. Six stations were selected along the Old Welland Canal (three instream stations and three effluents) and three instream stations along Twelve Mile Creek. In addition, each of the five St. Catharines beaches were sampled at a 1 metre depth from shore. Water samples for bacteriological analysis, temperature, pH and dissolved oxygen were taken under dry weather conditions at each station at four hour intervals.

The bacterial results are summarized in Tables 4.8, 4.9. and 4.10. The relatively high water temperature of nearly 25°C in the Old Welland Canal (First Fall and Tricell Outlet stations) may be attributed to the elevated water temperatures from Ontario Paper and Domtar Construction effluents; these also had the lowest dissolved oxygen values. By contrast, the three instream stations in Twelve Mile Creek showed water temperatures nearly 4°C lower than the Old Welland Canal and higher dissolved oxygen values.

The fecal coliform concentrations in the instream stations of the Old Welland Canal increased. Levels increased from a geometric mean low of 453 fecal coliforms/100 ml as background value at the Intake station to nearly 700,000 org./100 ml at John Street and about 200,000 org./100 ml at the Tricell Outlet. Domtar Construction final effluent contributed the highest level with a geometric mean of 56,740,419 org./100 ml. Carter Creek also contributed to high fecal coliform values to the Canal, but its volume of water output was significantly lower than Ontario Paper. The bacterial load into Twelve Mile Creek from the Old Welland Canal increased the fecal coliform level from a background geometric mean of 354 org./100 ml at Glendale to approximately 5,000 org./100 ml downstream from the confluence with the canal.

Two major species of bacteria were identified in the fecal coliform group. Klebsiella sp. consistently comprised the larger proportion compared with E. coli in both the Old Welland Canal effluent and instream stations and in Twelve Mile Creek. The relative proportions of these groups of bacteria in these two streams are plotted in Figures 4.4 and 4.5. The high levels of Klebsiella sp. are indicative of pulp and paper wastes in the canal and creek. It is worth noting that the highest geometric mean value of Klebsiella

TABLE 4.8

ST. CATHARINES OFF-BEACHES SURVEY DATA SUMMARY

SEPTEMBER 22 - 25, 1985

Station Description	Geometric Mean Organisms/100 ml					Arithmetic Mean			
	Fecal	E. coli		Klebsiella	Percentage E.coli/Fecal MUG	Estimated flow m^3/s	Dissolved Oxygen mg/l	Temp C	pH Units
		mTEC-IG	MUG						
Old Welland Canal-Intake	453-14	23-14	12-5	155-14	2.6	1.4	9.8	20.6	8.0
Ontario Paper Final Effluent	234,241-15	13,449-14	2,865-6	170,933-14	1.2	1.5	6.3	31.1	6.8
Domtar Construction Final Effluent	56,740,419-15	899,840-15	9,207-6	3,388,729-15	0.016	0.0080	4.9	35.5	7.2
Old Welland Canal - John Street	699,706-15	9,355-15	2,981-3	347,147-15	0.4	3.2	8.5	24.7	7.1
Carter Creek	650,716-15	253,640-15	163,261-3	143,318-15	25	0.089	9.5	19.4	7.7
Old Welland Canal-Tricell Outlet	200,314-15	3,822-15	1,558-3	78,034-15	0.78	3.5	6.6	24.9	6.3
Twelve Mile Creek-Glendale Ave.	354-15	42-15	70-3	165-15	20	180	10.2	20.2	7.5
Twelve Mile Creek-Fourth Ave.	5,002-15	144-15	41-3	3,071-15	3.0	180	10.1	20.4	7.5
Twelve Mile Creek-Lakeport Road	4,046-15	99-15	230-3	3,004-15	5.7	180	10.2	20.3	8.2
Lakeside Park Beach	225-4	22-4	-	222-4	9.8*	-	10.3	19.6	8.4
Michigan Beach	789-4	37-4	-	1,151-4	4.7*	-	10.2	20.4	8.3
Garden City Beach	157-2	110-2	-	130-2	71*	-	9.7	24.0	8.5
Municipal Beach	56-2	23-2	-	130-2	41*	-	9.9	22.5	8.5
Jones Beach	32-2	20-2	-	14-2	63*	-	9.4	22.5	7.9

*$mTEC_{IG}$/MF procedure used

TABLE 4.9

ST. CATHARINES OFF-BEACHES SURVEY LOADS

SEPTEMBER 22 - 25, 1985

Station Description	Load Organisms/sec x 10^8		
	Fecal	E. Coli	Klebsiella
Old Welland Canal-Intake	0.063	0.0017	0.022
Ontario Paper Final Effluent	35	0.43	26
Domtar Construction Final Effluent	45	0.0074	2.7
Old Welland Canal - John Street	22		
Carter Creek	5.8	1.5	1.3
Old Welland Canal-Tricell Outlet	70	0.54	27
Twelve Mile Creek-Glendale Ave.	6.4	1.3	30
Twelve Mile Creek-Fourth Ave.	90	0.74	55
Twelve Mile Creek-Lakeport Road	73	4.1	34
Lakeside Park Beach	-	-	-
Michigan Beach	-	-	-
Garden City Beach	-	-	-
Municipal Beach	-	-	-
Jones Beach	-	-	-

TABLE 4.10
ST. CATHARINES OFF-BEACHES SURVEY STATISTICS SUMMARY,
ORGANISMS/100 ML
SEPTEMBER 22 - 25, 1985

	E. Coli ($_m{}^T$ECIG)			Fecal Coliform			Klebsiella sp.		
Station Description	Min.	Max	Median	Min	Max	Median	Min	Max.	Median
Old Welland Canal-Intake	4	100	22	56	2,400	450	12	650	215
Ontario Paper Final Effluent	1,000	100,000	11,000	59,000	800,000	240,000	20,000	400,000	240,000
Domtar Construction Final Effluent	9,200	10,000,000	1,000,000	1,000,000	230,000,000	70,000,000	100,000	51,000,000	6,800,000
Old Welland Canal-John St.	100	100,000	10,000	130,000	3,600,000	610,000	40,000	1,100,000	470,000
Carter Creek	43,000	560,000	280,000	270,000	2,700,000	540,000	10,000	400,000	180,000
Old Welland Canal-Tricell Outlet	700	100,000	2,400	67,000	480,000	240,000	1,000	260,000	110,000
Twelve Mile Creek - Glendale Ave	5	560	45	30	2,400	320	10	1,300	180
Twelve Mile Creek-Fourth Ave.	10	700	200	1,600	14,000	5,100	1,300	5,300	3,000
Twelve Mile Creek-Lakeport Rd.	20	200	100	800	10,000	4,800	940	8,100	3,200
Lakeside Park Beach	10	30	28	95	680	200	140	600	170
Michigan Beach	20	100	30	270	3,200	670	780	3,000	870
Garden City Beach	4	3,000	1,502	4	6,200	3,102	4	4,200	2,102
Municipal Beach	10	54	32	2	1,540	771	10	1,700	855
Jones Beach	12	32	22	20	52	36	10	20	15

sp. was recorded from Domtar Construction effluent (approximately 3,400,000 org./100 ml) a source of paper fibre, while the highest mean value of E. coli at 160,000 org./100 ml was recorded from Carter Creek which carries a higher proportion of sanitary sewage.

4.2 Beaches

Fecal coliform data for the five beaches at St. Catharines was available for the summers of 1983 (3) and for the four surveys during 1984 and 1985. A comparative analysis of the geometric means as shown in Figure 4.6 indicate considerable variations in fecal coliform concentrations from summer to summer as well as within each summer period. In the summer of (June - August) 1983 fecal coliform concentrations for each of the five beaches were all above the MOE criterion of 100 org./100 ml, with a minimum of 150 org./100 ml found at Jones Beach and a maximum of 590 org./100 ml at Garden City Beach (3).

In the July 9 - 11, 1984 survey a greater variation in concentrations was observed, with a minimum of 20 org./100 ml found at Jones Beach and a maximum of 1,517 org./100 ml at Garden City Beach. The concentrations in the other three beaches were above the MOE criterion of 100 org./100 ml.

In the August 28-30, 1984 survey, fecal coliform levels of 70 org./100 ml for Lakeside Park Beach and 20 org./100 ml for Jones Beach were noted. The other three beach areas had increased to over 1000 org./100 ml. The resulting fecal coliform concentrations were 1,040 org./100 ml for Garden City Beach, 1,340 org./100 ml for Michigan Beach and 3,900 org./100 ml for Municipal Beach.

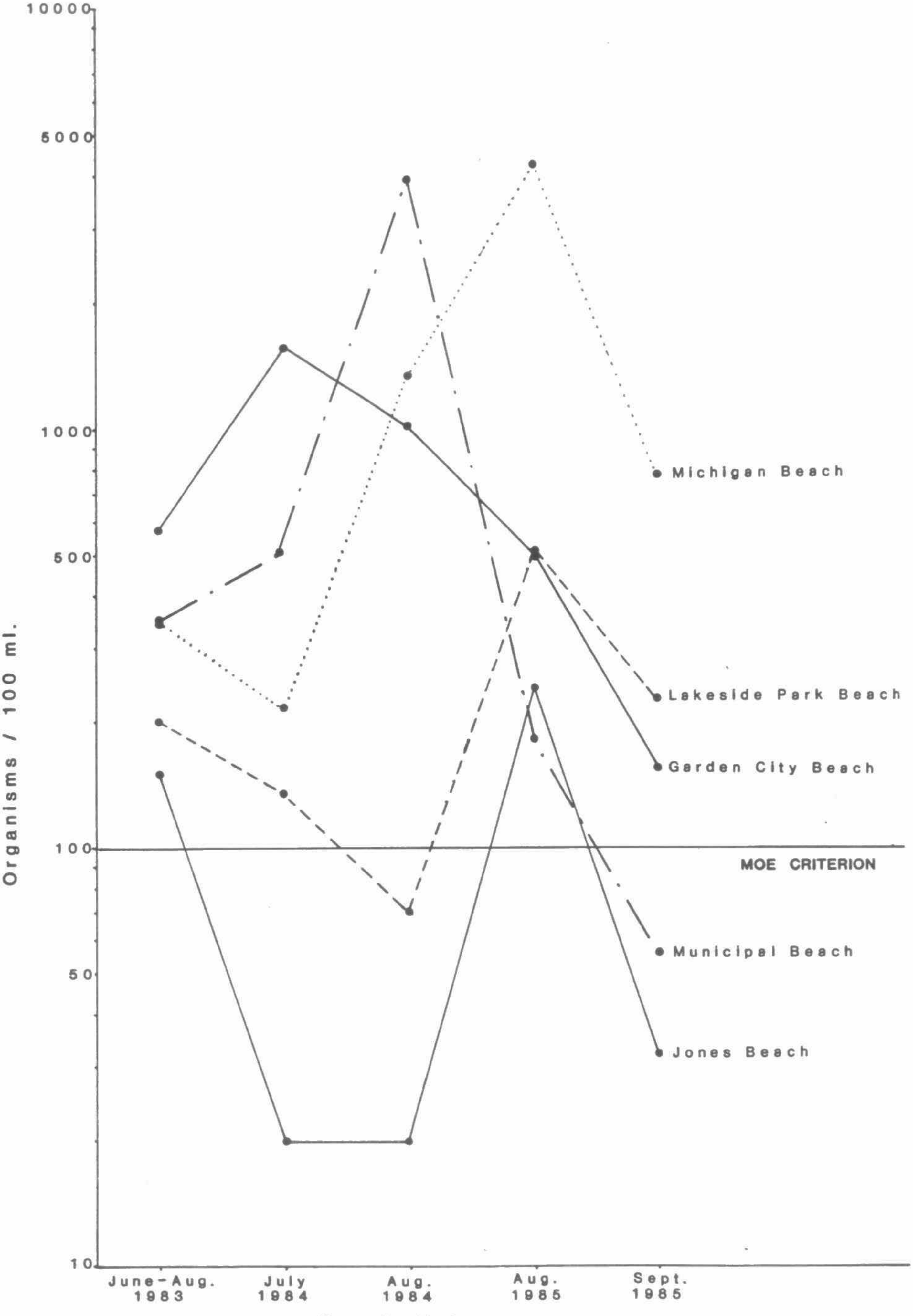


Figure 4.6 : St. Catharines Beaches Fecal Coliform Levels 1983 - 1985

In the August 12-15, 1985 survey, fecal coliform concentrations displayed the highest levels observed for four of the five beaches of the five survey periods. This also coincided with the highest values observed with the instream survey. The highest concentrations occurred at Michigan beach with a geometric mean of 4,248 org./100 ml. The concentrations for the other four beaches ranged from 181 org./100 ml to 553 org./100 ml. In this respect, these values were similar to those of the June-August 1983 survey with the exception of Garden City Beach.

In the September 22-25, 1985 survey, a decrease in fecal coliform concentrations occurred in all five beaches, relative to the August 1985 survey. Both Municipal and Jones beaches were below guideline levels, with 56 and 32 org./100 ml respectively, while the other three beaches remained above 100 org./100 ml. The highest value of 789 org./100 ml was recorded at Michigan Beach, and intermediate values of 157 and 225 org./100 ml were recorded at Garden City and Lakeside Park beaches respectively.

E. coli data were also collected at all five beaches during the five surveys (Figure 4.7). E. coli concentrations exceeded the recommended guideline of 23 org./100 ml proposed by the Great Lakes Science Advisory Board of the IJC (6). Jones Beach exceeded the proposed guideline in two of the five surveys with the remaining beaches exceeding the level by four times or greater. Therefore, if the proposed guideline for E. coli is implemented, the beaches will still remain posted.

In summary, four of the five beaches at St. Catharines remained permanently posted during the summers that surveys were carried out. Only Jones Beach remained open for the majority of the summer periods, being closed on a temporary

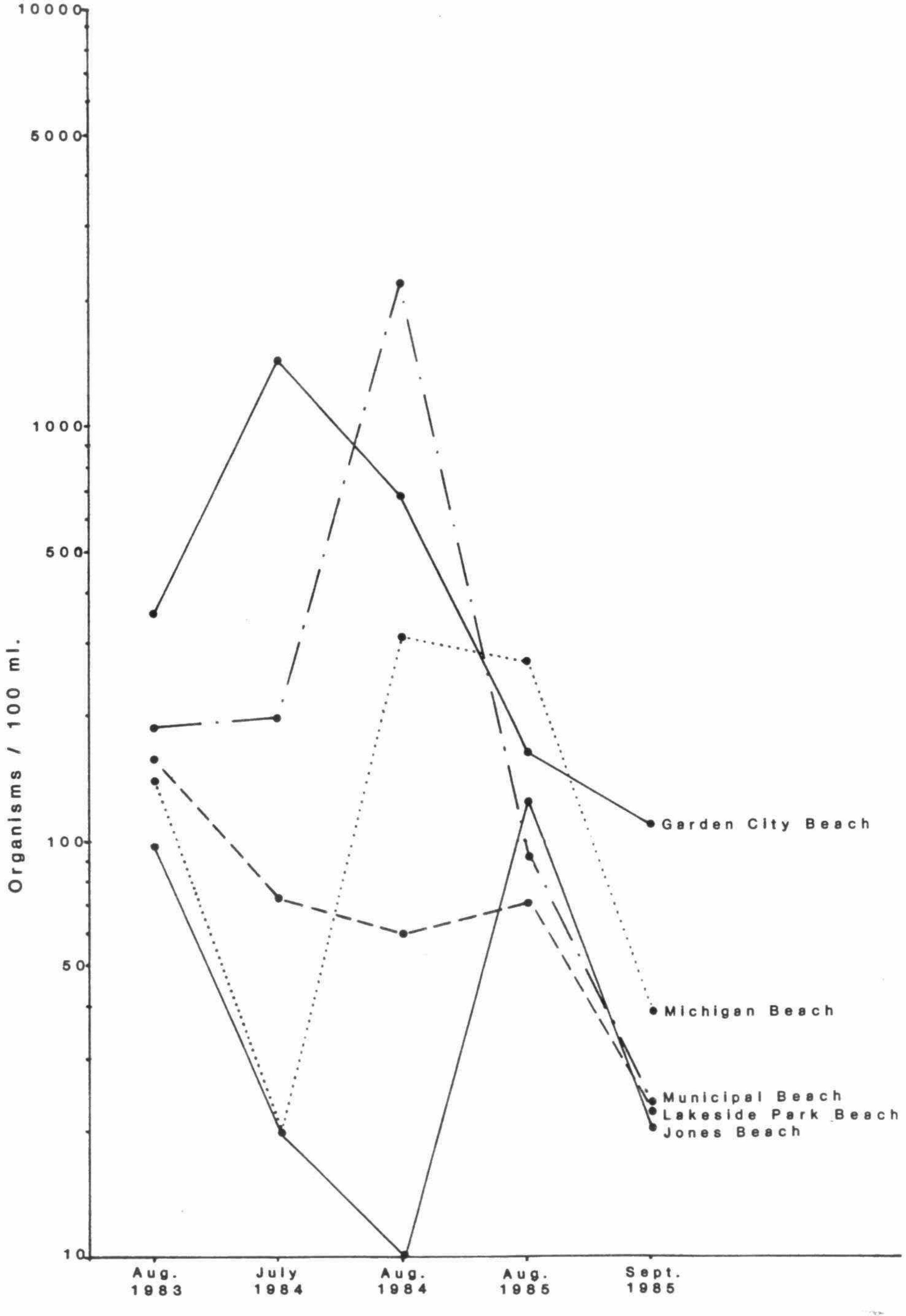


Figure 4.7 : St. Catherines Beaches E. Coli Levels, 1983 - 1985

basis. The low levels of bacteria found at Jones Beach can be attributed to the protection provided by the impervious Welland Ship Canal breakwall which extends far out into Lake Ontario.

Twelve Mile Creek also discharges out through a breakwall to Lake Ontario. However, this breakwall is not impervious so the Twelve Mile Creek water can mix with the lake water. This mixing likely causes bacterial contamination of the two adjacent beaches, Lakeside Park and Michigan. If these breakwalls were sealed, it is probable that Lakeside Park Beach and to a lesser extent Michigan Beach would be protected from continuous contamination by bacterial levels in the Twelve Mile Creek outflow. However, Municipal and Garden City beaches would probably still be impacted by the plume discharging from the mouth of Twelve Mile Creek.

4.3 Twelve Mile Creek Drainage Basin

A comparison of the fecal coliform results for the Old Welland Canal (OWC) for the summers of 1984 and 1985 are presented in Figure 4.8. The results indicate a major increase in fecal coliform concentrations in the background values at the OWC intake and Glendale Avenue locations as well as at the Old Welland Canal and Twelve Mile Creek downstream of the confluence of the Old Welland Canal. Fecal coliform concentrations were also very high in the Old Welland Canal at the Tricell outlet, John Street and Westchester Avenue. These high levels may be attributed to the industrial and municipal effluents contaminating these waters. The lower concentrations in the Twelve Mile Creek are due to the large dilution that occurs.

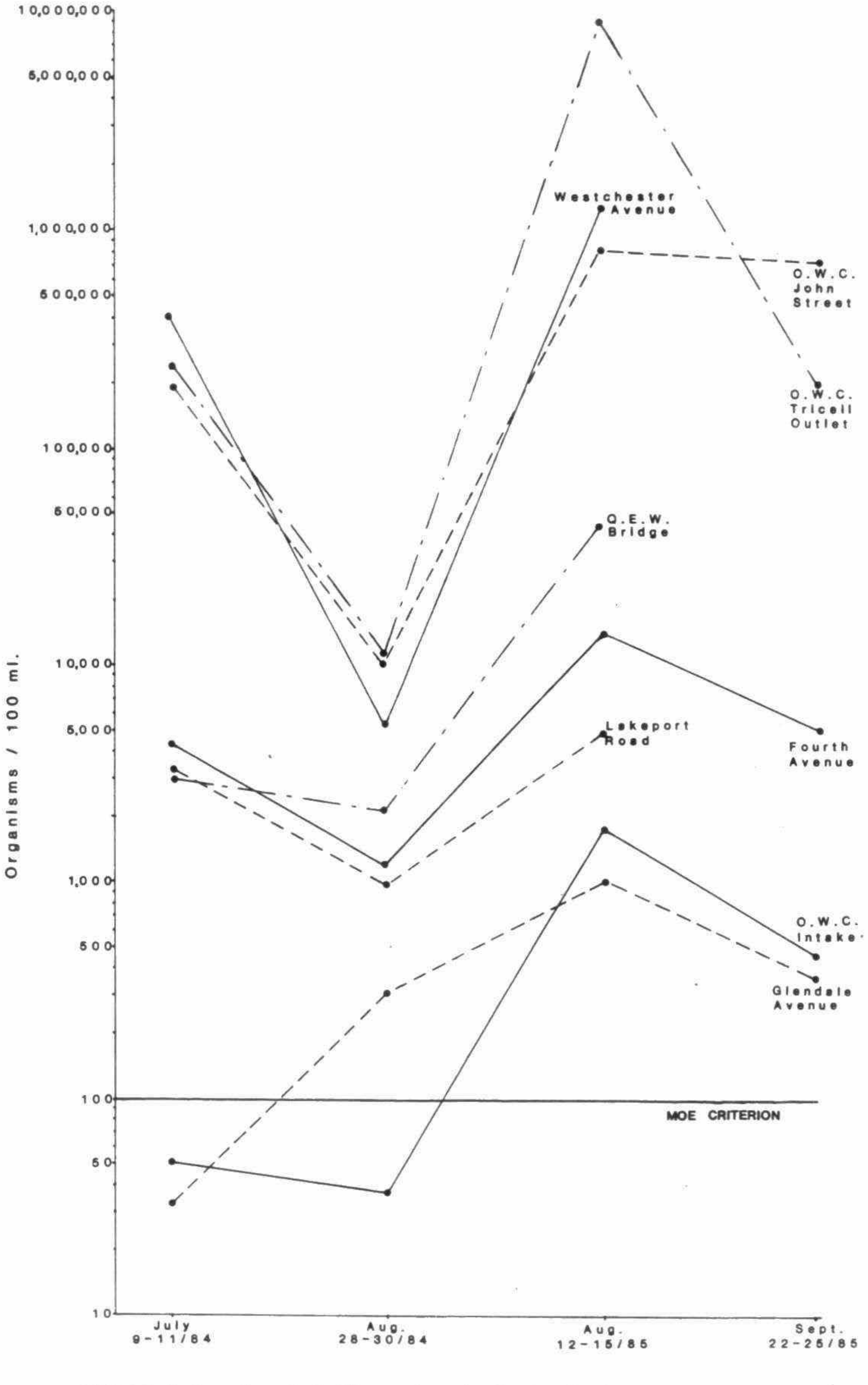


Figure 4.8 : Fecal Coliform Levels in Study Area

4.3.1 Old Welland Canal

Comparison of four stations for July 9 - 11, 1984 (Table 4.8), along the OWC shows elevated fecal coliform geometric means from a low of 51 org./100 ml at the OWC intake to 201,351 org./100 ml at the John Street station, 410,000 org./100 ml at Westchester and 262,770 org./100 ml at the Tricell Outlet. These elevated concentrations show a large change in water quality from the OWC intake due to industrial and municipal discharges.

In the August 28-30, 1984 survey, the fecal coliform level at the OWC Intake was similar to the previous month at 36 org./100 ml, but the three stations downstream in the Canal showed a considerable decrease in fecal coliform levels from the previous survey with geometric mean values recorded at 10,096 org./100 ml at the John Street station, 5,316 org./100 ml at Westchester and 11,698 org./100 ml at the Tricell Outlet. Nevertheless, these levels were still high in relation to the intake waters and indicate poor water quality for this area.

By contrast, in the August 12-15, 1985 survey, the fecal coliform concentration increased from the previous summer to a geometric mean of 1,489 org./100 ml at the OWC intake indicating a poorer water quality. The source of this contamination is unknown. A considerable increase in fecal coliform concentrations was also observed at the three stations downstream in the Canal with geometric means of 1,336,608 org./100 ml for John Street, 1,595,873 org./100 ml for Westchester Avenue and 2,355,745 org./100 ml at the Tricell Outlet. The similar fecal coliform levels at John Street, Westchester Avenue and Tricell Outlet stations indicate that there was relatively no die off or regrowth of fecal coliform organisms in the OWC.

In the September 22-25, 1985 survey, fecal coliform levels were 453 org./100 ml at the OWC intake. The concentration at John Street remained high at nearly 700,000 org./100 ml, but a considerable decrease in fecal coliform concentrations to nearly 200,314 FC/100 ml was found at the Tricell Outlet.

In summary, results shown in Figure 4.8 indicate that consistently high concentrations of fecal coliform organisms occurred along the Old Welland Canal during the summers of 1984 and 1985. These elevated values relative to background levels are attributed to discrete effluent inputs into the Canal (Figure 4.9), derived primarily from the Ontario Paper effluent, Domtar Construction effluent and the Centennial Park 78" sewer for the summer of 1984 and again from the above first two point sources plus Carter Creek for the summer of 1985.

It should be noted that the comparison of fecal coliform levels from the 78" Centennial Park sewer showed a dramatic decrease between the summer of 1984 and 1985 (Figure 4.9). However, this decrease was offset by a simultaneous increase in loading from Carter Creek in August 1985. Some improvement was also observed in the Ontario Paper final effluent in July 1984 and August 1985, but a significant increase in fecal coliform output occurred again during the September 1985 survey.

4.3.2 Twelve Mile Creek

Fecal coliform concentrations in Twelve Mile Creek for the summers of 1984 and 1985 are plotted in Figure 4.8 for four stations along the creek. Background concentrations recorded at Glendale indicate a progressive increase from a geometric mean low of 32 org./100 ml in July 1984 to a high of 1,014 org./100 ml in August 1985 followed by a decrease

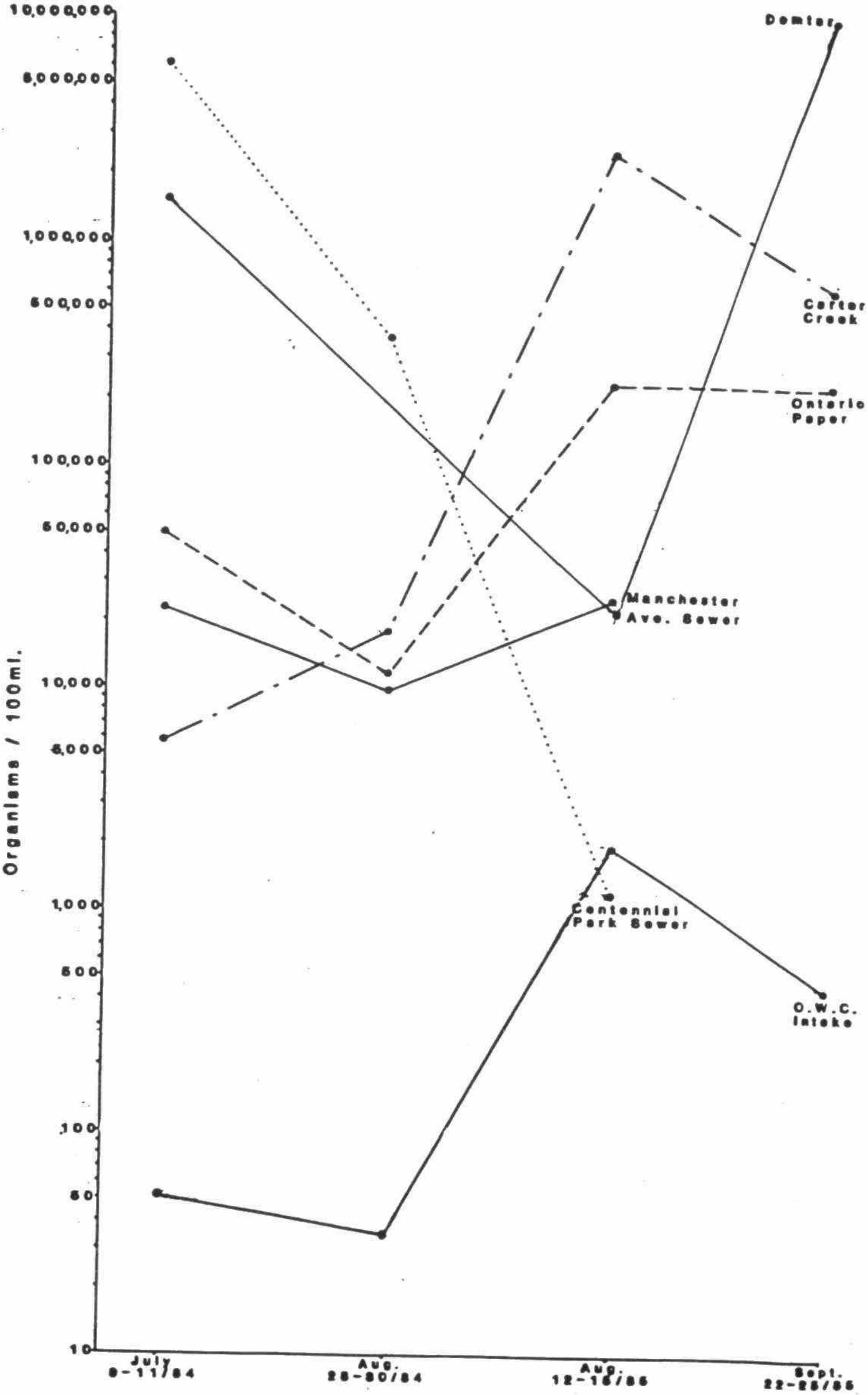


Figure 4.9 : Fecal Coliform Levels of Point Sources in Study Area

to 354 org./100 ml in September 1985. At the three stations downstream from the confluence with the Old Welland Canal (Tricell Outlet), the bacterial concentrations are consistently higher than background level. This trend follows closely the fecal coliform concentrations in the Old Welland Canal which stands out as a major source of contamination for Twelve Mile Creek.

4.3.3 Sewage Treatment Plants

The trends in fecal coliform concentrations in the treated effluents of the Port Weller and Port Dalhousie sewage treatment plants, (STPs) are shown in Figure 4.10. Both STPs show an increase in fecal coliform output into Lake Ontario with respect to time. The concentrations are substantially lower in the Port Dalhousie STP with a low geometric mean value of 14 org./100 ml in August 1983 rising to a high of 270 org./100 ml in August 1985. These low concentrations are within acceptable values and have little impact on the loading in the surrounding beaches. When compared with fecal coliform geometric mean values of 33,000 org./100 ml from the mouth of Twelve Mile Creek, the amount discharged from the Port Dalhousie STP into Twelve Mile Creek becomes rather insignificant.

By contrast, the output of fecal coliform from the Port Weller STP into the Welland Ship Canal is significantly higher with geometric mean values of 60 org./100 ml in August 1983 that rise to a high of 12,488 org./100 ml in August 1985.

Although the output from Port Weller STP is greater, its impact on the beaches may not be that significant considering the large dilution and dispersion factors of the Welland Ship Canal. The geometric mean coliform count in

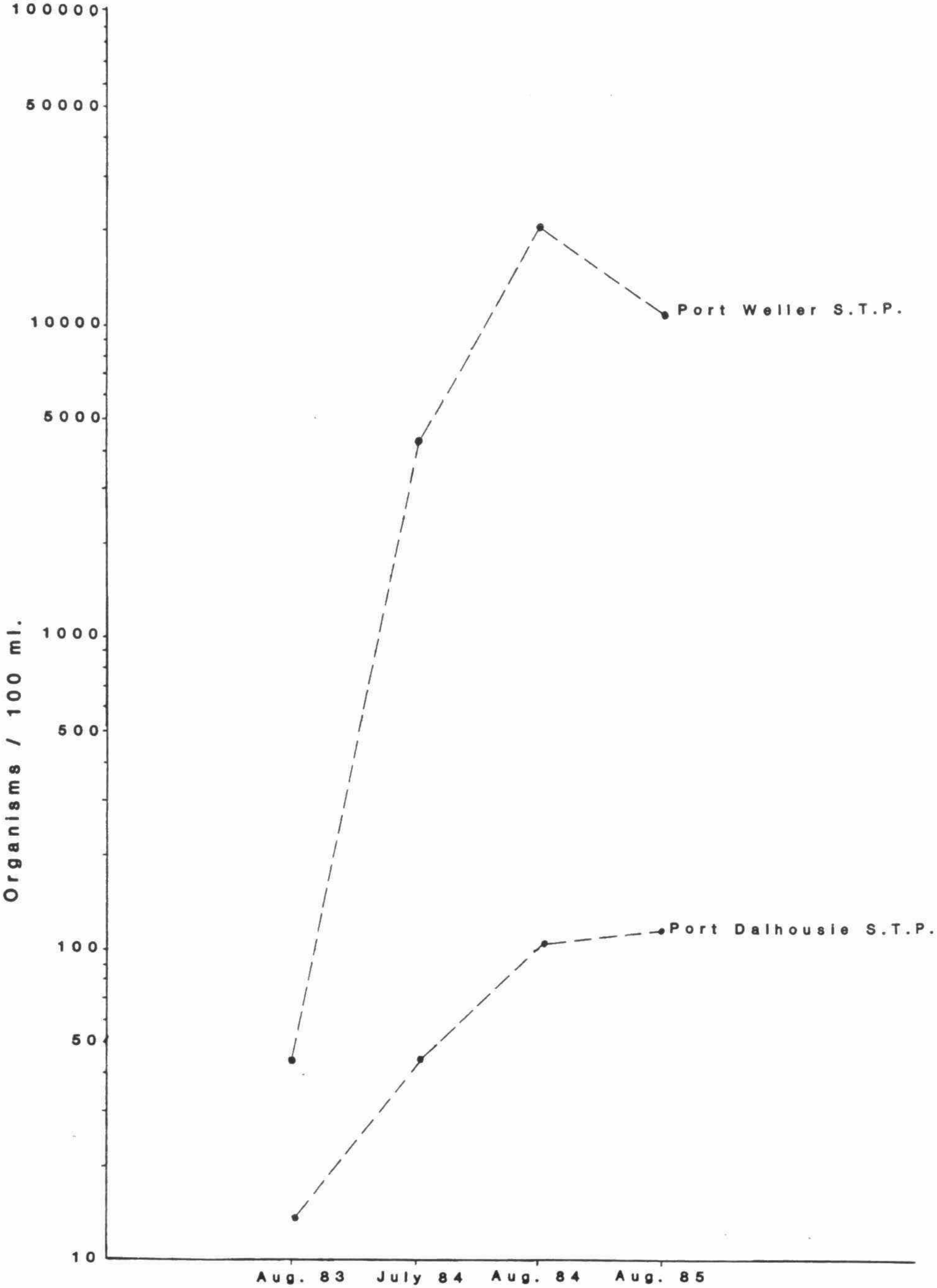


Figure 4.10 : Fecal Coliform Levels at Port Dalhousie and Port Weller Sewage Treatment Plants

August 1985 was only 14 org./100 ml at the Welland Ship Canal mouth. In addition, the outflow does not disperse through the breakwalls and lake currents generally sweep the outflow from the Welland Ship Canal away from the beach areas.

4.4 Interferences with Bacteriological Tests

Prior to September 1985, all off-beach samples were treated the same and analyzed according to the methods requested. During the August 1985 survey, it became apparent that the paper mill effluent was causing a problem with sample analysis. Pulp and paper waste which contains high levels of urease negative Klebsiella sp. and non-target micro-organisms is known to affect the specificity of the standard E. coli procedure (mTEC/urease). In essence, the E. coli test proves to have very low specificity (approximately 50%) in areas impacted by pulp and paper mill waste. Since the beaches' sampling points were not impacted by the pulp and paper mill effluents as greatly as other sampling points, the E. coli data from these sites have a more acceptable specificity (80%).

As a result of a meeting between West Central staff and Central Laboratory Microbiology staff in the fall of 1985, a further less intensive survey was planned for the week of September 22, 1985. The week prior to this survey, twelve samples were submitted to allow specificity testing of new tentative E. coli methods and the Klebsiella method. The performance testing demonstrated that the method of choice for analyzing these pulp and paper samples was an MPN procedure utilizing methylumbelliferyl-B-D-glucuronide (MUG). It had a specificity of greater than 90%.

However, because of an insufficient supply of MUG medium, only selected stations could be analyzed with the MUG/MPN procedure during the September survey. The E. coli data from this method can be considered to provide the most accurate estimate of E. coli concentrations.

The mTEC-IC/MF procedure which was used to analyze all samples for E. coli was found to have a specificity of approximately 75% when combined with the urease step. Although this is an improvement over the mTEC/urease procedure, this specificity is still not satisfactory and the values provided were for the most part considered approximations due to the large ratio of non-target (background) to target colonies. The problem in some cases was so bad that the lab staff were trying to identify one or two target "colonies" on a filter totally overgrown with non-target colonies.

The Klebsiella mF procedure (mK) used in 1985 had somewhat improved specificity over previous years as a result of an increase in the concentration of the antibiotic carbenicillin in the medium. The specificity of the 12 samples submitted was 95%. The improved performance of mK agar should not have a significant effect on the 1984 pulp and paper data because of the high relative concentrations of Klebsiella in the waste. One point that should be made is that the count obtained by the mK method is of Klebsiella species not necessarily K. pneumoniae sensu stricto. Further testing of isolates is required to determine if the actual species identification is of the bacteria being enumerated.

5.0 Discussion

A comparison of loads of fecal coliform organisms from various point sources for the July 1984 survey (Table 4.1) shows that Ontario Paper, Domtar Construction and the Centennial Park 78" sewer comprised the three major sources of fecal coliform input into the Old Welland Canal. The load from the intake to the end of the Canal at the Tricell outlet, increased from 0.0071 x 10^8 to 92 x 10^8 org/sec. This input from the Old Welland Canal was in turn the major source of contamination of Twelve Mile Creek which showed a load increase from a background of 0.64 x 10^8 organisms/sec at the upstream control station to 20 x 10^8 organisms/sec at the creek mouth.

Similarly, for the survey of August 1984, the major loads of fecal coliform into the Old Welland Canal (Table 4.3) originated from Ontario Paper, the Centennial Park sewer and to some extent Carter Creek. These sources to the canal in turn affected Twelve Mile Creek whose load, although at a relatively elevated background level of 5.6 x 10^8 org/sec at Glendale, increased at its mouth to 67 x 10^8 org/sec. The high load of Klebsiella sp. at 52 x 10^8 org/sec near the mouth of Twelve Mile Creek indicates that this bacteria may also be a major source of contamination at St. Catharines beaches. As indicated in Table 4.3 the major sources of Klebsiella sp. for the August 1984 survey were Ontario Paper and the Centennial Park 78" sewer.

In the survey of August 1985 (Table 4.5) the background load at the intake of the Old Welland Canal was nearly 12 times higher in the previous summer and ten times higher than the load input from the Domtar Construction effluent. The two major sources of fecal coliform to the Canal for this survey were Ontario Paper with a load of 33 x 10^8 organisms/sec and Carter Creek with 22 x 10^8 organisms/sec. In 1984, the Centennial Park sewer was a major source of fecal coliform to the canal; in 1985 this became a relatively insignificant source with a load one thousand times less than the 1984 levels. However, this decrease of fecal coliform load from the Centennial Park sewer was accompanied by a simultaneous increase in load from Carter Creek in 1985. These combined sources increased the load in the Old Welland Canal from the intake background value to its confluence with Twelve Mile Creek at the Tricell Outlet by a factor of 1,000 (Table 4.5).

In August 1985, the background load in fecal coliform from Twelve Mile Creek at Glendale Avenue, was nearly 100 times higher than that of the previous summer and only 10 times less than that was inputted from the Old Welland Canal. Hence, in August 1985, the Canal was not the only major source of fecal coliform organisms to Twelve Mile Creek, since the Creek itself upstream of its confluence with the Canal high bacterial levels. The Canal and the Creek combined contributed to a final load at the Creek mouth of 590 x 10^8 organisms/sec which resulted in the summer posting of beaches in St. Catharines.

For the survey of September 1985, the differentiation of E. coli and Klebsiella sp. from the fecal coliform organisms is reported in Table 4.8. Ontario Paper, Domtar Construction and Carter Creek are the three primary sources contributing heavy loads of fecal coliform organisms comprised largely of Klebsiella. Background loads in Twelve Mile Creek, at Glendale Avenue, were again relatively high in September 1985 for all these groups of organisms, being only 10 times lower than those of the Old Welland Canal at the confluence with Twelve Mile Creek for the fecal coliforms (Table 4.9). This indicates, as for the August survey, that Twelve Mile

Creek upstream from the Old Welland Canal is a significant source of bacterial contamination. It is significant to note that the majority of the fecal coliform organisms present at the St. Catharines Beaches are Klebsiella (Table 4.8).

6.0 CONCLUSIONS AND RECOMMENDATIONS

The two bacteriological surveys conducted during 1984 identified the Old Welland Canal as being the major source of contamination to Twelve Mile Creek and thus to Lakeside Park, Michigan, Garden City and Municipal Beaches. Twelve Mile Creek is unlikely to impact upon Jones Beach since the beach is protected by the Welland Ship Canal breakwall. Bacterial data collected during 1985 not only identified the Old Welland Canal as a major source of contamination but also indicated that upstream waters contributed significantly to water quality degradation.

Domestic sewage and paper mill effluents were identified as the main bacterial contamination sources to the Twelve Mile Creek system during dry weather. Many illegal connections and poorly operating combined sewer overflow structures were responsible for the domestic sewage contributions. Ontario Paper and Domtar Construction were responsible for the majority of the bacterial contamination associated with paper mill effluents.

Centennial Park sewer outfall was the highest single source of fecal coliform contribution during the July 1984 instream survey. This and other minor sources were reported to the City of St. Catharines Engineering Department for corrective measures and by the following year these outfalls contributed significantly less bacterial contamination.

Carter Creek, Dick's Creek and McKenzie Drain show evidence of fecal coliform contamination. Carter Creek's water quality deteriorated severely during 1985 and has become a significant bacterial source.

Bacterial contamination increased significantly at both sewage treatment plants within the study area during the four surveys. Bacterial levels in the Port Dalhousie STP effluent was considered to be acceptable. However, during 1985, the Port Weller STP produced a significant bacterial load. This input does not contribute significantly to beach contamination in this area because of the large dilution that occurs in the Welland Ship Canal, as well as the lack of dispersion with lake water near-shore and the impermeable breakwall barriers.

Klebsiella inhabiting the nutrient-rich paper mill effluents interfered with the specificity of the E. coli analyses carried out during the first three surveys. New test procedures were developed, tested and applied in the fourth survey. It was found that the paper mill effluents contained a ratio of less than 2% E. coli/fecal coliform. However, considering the amount of effluent being discharged, these sources are still significant.

In light of the above conclusions, the following recommendations are made:

1. Further bacterial source identification work should be conducted to locate contamination upstream of Glendale Avenue in Twelve Mile Creek.

2. Bacterial contamination in Ontario Paper and Domtar Construction effluents should be reduced.

3. Bacterial contamination in Carter Creek, Dick's Creek and McKenzie Drain should be identified and reduced.

4. Treatment practices should be improved at Port Weller STP to reduce bacterial levels in the effluent.

5. All combined sewer overflows in St. Catharines and Thorold should be located so they can be inspected and maintained in good working order especially during swimming months.

6. All storm sewers should be inspected for illegal connections and where found, corrected.

7. A wet weather survey should be carried out to evaluate the impact of storm sewer and combined sewer overflows on the beaches and Twelve Mile Creek.

8. In co-operation with the Ministry of Health, the health significance of *Klebsiella* should be determined.

9. The possibility of revising bathing and swimming standards to specifically include *E. coli* should be continued.

10. An optimization model should be developed for predicting the response of beaches' bacterial levels to reductions of various inputs. This model would provide guidance for the two cities and the Regional Municipality in prioritizing remedial work to be completed on combined sewer overflows and sewage treatment by-passes.

11. A further study indicating the extent of the Twelve Mile Creek directly impacting the adjacent beaches through the pervious breakwalls should be carried out. If this impact is deemed significant, then a pre-engineering cost estimate of sealing the breakwalls of Twelve Mile Creek to protect Lakeside Park and Michigan beaches from bacterial contamination should be carried out.

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